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INDICES OF PERIODONTAL DISEASE

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A thesis submitted in partial requirement for
the Diploma in Public Health Dentistry

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Periodontal disease is a very common condition among the dentate population. A description of its severity rather than its mere presence or absence is essential for both the epidemiologist and the clinician in evaluating the disease.

The first attempt in objective quantification of periodontal disease began in 1947 with the PMA Index of Shour and Massler. This was followed by Russell's Periodontal Index (PI 1956), Ramfjord's Periodontal Disease Index (PDI 1959) and Greene and Vermillion's Oral Hygiene Index - Simplified (OHI-S 1964). Also in 1964, Silness and Loe developed the Gingival and Plaque Indices (GI and PLI) for use in experimental gingivitis studies.

Many other indices have since evolved from these indices according to the particular researcher's needs. Only those conforming closest to the following requirements will be reviewed in this treatise:

1. Simple to use at minimal time and cost;
2. Possessing a high degree of inter- and intra-examiner reproducibility;
3. Indicate in a meaningful way the clinical stages of the disease;
4. Amenable to statistical analysis.

Periodontal indices can be classified into four broad groups according to the various periodontal disease parameters which they purport to measure:
1. etiologic factors (soft and hard oral deposits);
2. and 3. degree of gingival inflammation and periodontal destruction of supporting soft tissue and bone and
4. the periodontal treatment needs of individuals or populations.

Soft Deposits

Four types of measurements are used in assessing the accumulations of oral soft deposits. The plaque area method includes various numerical indices (eg. Ramfjord's PDI, O'Leary's GPI, Green & Vermillion's OHI-S) and the quantification of area by photographs and area measuring devices. The thickness of plaque is the scoring criterion in the Pl I of Silness & Loe. Plaque weight provides another alternative measurement. Furthermore, the quantity and quality (eg. the pathogenic potential as related to specific organisms, concentration of endotoxins) of plaque can be estimated by laboratory techniques.

The selection of a particular index depends on the objective of the study, the method used and the nature of
any agents under test. Simplicity of application and reproducibility of results are the major criteria in choosing an index for epidemiological purposes. For clinical gingivitis and tooth cleaning studies, more finely graded indices emphasising the gingival one-third deposits are preferred.

Hard Deposits

Calculus can be measured by the calculus-measuring components of the PDI or OHI-S or by methods devised exclusively for clinical studies such as the Calculus Surface Index (CSI) of Ennever, Sturzenberger & Radike, the Marginal Line Calculus Index (MLC) of Muhlemann & Villa, and the Probe Method of Calculus Assessment of Volpe & Manhold.

In epidemiological studies, both the OHI-S and PDI have been extensively used. The choice of a calculus index for clinical studies is dependent on the purpose and the length of the study, the size of the population sample and the type and extent of deposits anticipated.

Degrees of Gingival Inflammation

The indices recording gingival inflammation can be classified into two categories: those using a present/absent dichotomous scale (eg. WHO 1977 Oral Health Survey Basic
Methods) and those using a graded severity scale (eg. PI of Russell, PDI of Ramfjord, GI of Silness & Loe, SBI of Muhlemann & Mazor).

The PI of Russell and PDI of Ramfjord are adequate for use in epidemiological studies. However, the critical evaluation of gingival inflammation in clinical trials can be difficult. The GI as compared to other parameters measuring gingival inflammation such as the biopsy method and gingival crevicular fluid flow is reviewed in the literature. The GI is found to be the index of choice in clinical studies. The reliability of gingival bleeding indices is questioned because of non-standardized probing pressures in eliciting gingival bleeding. Photographs are very useful in standardizing examiners but direct photographic methods of measuring gingivitis lack reliability.

**Degree of Destruction of Connective Tissue**

The destructive phase of periodontal disease is characterized by loss of epithelial soft tissue attachment, collagen fibres and in advanced destruction, the supporting alveolar bone.

The loss of epithelial attachment can be directly measured with a periodontal probe and is expressed as the distance in millimeters from the cemento-enamel
junction to the apical extent of the gingival sulcus or pocket. This is the method recommended for clinical evaluation of attachment levels. The periodontal component of the PDI converts millimeter measurements of attachment loss to corresponding scores on a scale. The PI of Russell records advanced periodontal breakdown without measuring the amount of attachment loss. Both PDI and PI are useful only in epidemiological surveys.

Various commercially available periodontal probes are reviewed. Accuracy of periodontal probing is found to be related to the probing pressure, the degree of tissue inflammation, quality of the probe, precision of the millimeter markings and various local anatomic factors.

The dental radiograph is the traditional method of assessing changes in the alveolar bone levels despite its various limitations in diagnosing bone loss. Radiographs are recommended particularly in long term clinical periodontitis studies in the comparison of interproximal bone levels. Numerous standardization techniques have been devised to improve the diagnostic quality of radiographs but none has achieved universal acceptance.

Periodontal Treatment Needs

Development of periodontal treatment need systems of evaluation began in the last decade. The 1971 and 1977
WHO Oral Health Surveys were designed for screening population periodontal treatment needs. The Community Periodontal Index of Treatment Needs (CPITN) is a further refinement of the method. Periodontal treatment needs are recorded in sextants with the use of a specially designed probe. The data available from the CPITN can reflect the polarization of the disease in different strata of the population. This enables the health planner to calculate manpower and cost of delivering treatment to the given population.
I wish to express my gratitude to my supervisor, Associate Professor P.D. Barnard, for his constant encouragement and guidance throughout the course, and to Dr Catherine Taylor, who assisted me with some of the library research work.
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1. INTRODUCTION

1.1 PERIODONTAL DISEASE

1.1.1 Etiology of Periodontal Disease

The periodontal diseases most commonly observed are gingivitis, periodontitis and their combination. They are defined as chronic, non-specific diseases and exclude the more special chronic conditions such as juvenile periodontitis and acute gingival and mucosal infections (WHO 1978).

The classical experiments of Loe and co-workers demonstrated the cause and effect relationship between bacterial plaque and gingivitis in man (Thelaide, Wright, Jensen & Loe 1966). The occurrence and degree of severity of gingivitis is closely related to oral hygiene practices (Lindke & Koch 1966; Loe, Rindom Schiott, Glavind & Karring 1976). A complete reversal from gingivitis to gingival health will take place if the adjacent tooth surfaces are maintained free of plaque for 6 - 8 days (Loe, Thelaide & Jensen 1965; Syed, Loesche & Loe 1975). Removal of the bacterial deposits by mechanical or chemical means has led to resolution of gingivitis in man and
animals. Recurrence of the disease can be prevented by maintenance of a strict plaque control regime (Axelsson & Lindhe 1981).

1.1.2 Progression of Periodontal Disease

Gingivitis constitutes the initial lesion in periodontal disease. It may or may not progress to periodontitis. Page & Schroeder (1976) proposed that there is either a modification or activation of the host response or a change in plaque pathogenicity which exacerbates the disease. Further explanation of the possible conversion of gingivitis to periodontitis based on immunological grounds has been offered by Seymour et al (Seymour, Powell & Davies 1979).

Recent reports indicate that the progression of periodontal disease is not continuous but occurs in cycles (Holborow, Pack & Watt 1983). Destruction occurs in relatively short periods of time which are followed by prolonged periods of inactivity (Goodson, Tanner, Haffajee, Sornberger & Socransky 1982). Thus a periodontal lesion may alternate between periods of exacerbation or remission. The rate of periodontal destruction is very difficult to assess clinically.
1.1.3 Prevalence and Incidence of Periodontal Disease

Periodontal disease is an extremely common condition among the dentate population. Epidemiologic studies measuring the prevalence and severity of periodontal disease have been made in populations of widely varied ethnic and cultural backgrounds.

Epidemiology aims to locate and measure accurately the disease in the community, and through analysis to provide for its control and prevention.

The data from these surveys indicate that the distribution of this disease is universal. In a New Zealand dental survey in 1976, Croxson reports that 98 percent of the population aged over 15 years and 60 percent of all natural teeth have some periodontal disease. (Croxson, McKegg & Hunter 1983).

There is an increase in prevalence and severity from childhood to old age (Shour & Massler 1947; Marshall-Day, Stevens & Quigley 1955; Littleton 1963; Sherp 1964).

It is apparent that the change from healthy gingiva to gingivitis takes place early in life (King 1944; Marshall-Day et al. 1955; Muhlemann & Mazor 1958) and that both the
number of individuals (Baume & Marechaux 1975) with gingivitis as well as the degree of severity within individuals (Mehta 1956; Parfitt 1957; Croxson et al 1983) increase through the teens and early twenties.

Several surveys have demonstrated that periodontal conditions improve as the years of formal education increase (Russell 1957; Mobley & Smith 1963; Bradtzaeg & Jamison 1964; Sheiham & Striffler 1970) and as the income goes up (Ramfjord 1961; Sheiham & Striffler 1970). In well developed countries where low income groups can afford to have an adequate diet, the differences can be attributed to the difference in oral hygiene status and dental care (Russell & Ayers 1960).

Surveys in developed countries reported no difference in severity of periodontal disease between urban and rural populations (Sheiham & Striffler 1970; Croxson et al 1983). However Greene (1960) reported that the rural population of India had greater prevalence and severity in periodontal disease than the urban population.

Females have better periodontal health in surveys carried out in Western countries (Bossert & Marks 1956; Russell 1957; Croxson et al 1983). They seem to be more preventive orientated and practise oral hygiene better than the males, despite the fact that the female sex hormone in some way or other aggravates the inflammatory gingival
conditions during puberty, pregnancy and menopause (Silness & Loe 1964; Lindhe & Attstrom 1967). In less developed countries, the sex difference seems to be absent or reversed (Harris 1961; Guta 1964).

Periodontal disease is the major oral health problem in developing third world countries. In a national study in Nigeria, there was a dramatic increase in the number of young adults with periodontal pocketing after age 14. By 50 to 59, 100 percent of the population is affected (Sheiham 1981).

1.1.4 Teeth Mortality Rates in Periodontal Disease.

The number of teeth lost due to periodontal disease increases with advancing age (Marshall-Day et al 1955). After the fourth decade, periodontal disease is a major cause of tooth loss (Krogh 1958). The 1977 Illinois Conference (Chilton & Miller 1981) concluded that periodontal disease is a major cause of tooth loss in adults.

However in a comparative longitudinal study of periodontal disease between Norwegian academicians and Sri Lankan tea labourers, the average Norwegian suffers no tooth loss due to periodontal disease at age 40. The average Sri Lankan by age 30 has loosening teeth due to advanced periodontal disease (Loe, Ånerud, Boysen & Smith 1978).
Barclay (1974) in surveying dental extractions in New Zealand, showed that 51 percent of teeth were extracted for caries, 14 percent for prosthetic reasons and only 10 percent for periodontal reasons. The 1976 New Zealand national survey also revealed that only 3.6 percent of persons needed one or more teeth extracted for periodontal disease (Croxson et al. 1983).

These evidences point to the fact that despite its wide prevalence, periodontal disease is not a dentition threatening condition in countries where there is a systematic personal dental care from childhood.
1.2 PERIODONTAL INDICES

Periodontal disease is such a common condition that a recording of its mere absence or presence is not sufficient for either the epidemiologist or the clinician. It frequently varies in severity from tooth to tooth within the individual. It is necessary to describe differences in severity rather than prevalence. This variability in severity together with the lack of precise diagnostic criteria lead to many difficulties in quantifying periodontal health and disease.

1.2.1 History of Development of Periodontal Indices

One of the first attempts at categorizing periodontal disease was by Arthur D. Black in 1918. He used only a questionnaire and roentgenographic evidence to investigate what percentage of the population at various age levels had evidence of "periodontal" infection" (Black 1918).

Ainsworth and Young (Ainsworth & Young 1925) studied gingivitis in 4063 children from 2 to 14 years of age and classified them as having no, slight, intermediate or severe gingivitis. Day in 1944 examined 613 healthy Indian school children 4 to 16 years of age. Gingivitis was noted in 47.4 percent of the children from 5 to 10 years old and 73.2 percent in the 11 to 15 age group (Marshall-Day & Tandan 1944).
So far these studies used arbitrary and subjective methods in evaluation of mild, moderate and severe gingivitis. Such recordings did not enable comparison between different groups of subjects or even between subjects within a group since there were no clear criteria outlining the various levels of severity in the studies.

The periodontal index systems later developed had all been constructed to serve specific purposes. The first attempt towards objective quantification of the severity of gingivitis was the PMA Index published by Schour & Massler in 1947 (Schour & Massler 1947) in the assessment of gingival conditions of post-war Italian children.

The next step in the development of periodontal indices pertained to the time period when the World Health Organisation sponsored a series of epidemiological studies in the Far East.

The Periodontal Index (Russell 1956), the Periodontal Disease Index (Ramfjord 1959) and the Oral Hygiene Index (Greene & Vermillion 1960) were all constructed to allow rapid screening of large populations with advanced periodontal involvements.

A new era in the development of indices for plaque and gingivitis commenced when more recent investigators attempted to implement these various techniques for use in
Experimental studies. Silness and Loe proposed the Gingival Index and Plaque Index in the early sixties (Silness & Loe 1964) and demonstrated the correlation between plaque and the initiation of gingivitis.

Problems of causative relationships in periodontal disease have been solved. From the seventies on, periodontal indices are no longer tools only for the advanced researcher. Indices for periodontal treatment needs have been developed to enable the dental practitioner to classify patients into treatment categories according to their periodontal conditions (Johansen, Gjermo & Bellini 1973; Ainamo, Barnes, Beagrie, Cutress, Martin & Sardo-Infirri 1982) and hence expediate their treatments.

1.2.2 Objectives of Periodontal Disease Indexation.

The objectives of a periodontal scoring system have been summarized by Ramfjord (Ramfjord 1959).

1. To map distribution of the disease (prevalence)
   a) in population groups
   b) within each dentition
   c) around each individual tooth.

2. To record the progress and behaviour of the disease either by longitudinal studies of the same group or by
comparing prevalence studies of various age groups within the same population (incidence).

3. To investigate various etiologic factors in the pathogenesis of periodontal disease.

4. To estimate the total need for periodontal therapy in population groups.

5. To educate the dental profession, the public and government authorities regarding the need for periodontal care and treatment.

6. To estimate future needs for dentists and auxiliary personnel.

7. To evaluate the clinical effectiveness of various procedures or agents in the prevention and treatment of periodontal disease.

8. To enable the general practitioner to accurately classify patients into disease categories and quickly relate them to treatment.
1.2.3 Requirements of a Periodontal Disease Index

In evaluating a periodontal index, Hazen outlined the following requirements (Hazen 1974):

1. An index must be simple to use and permit the study of large numbers of persons with a minimum of time and cost.
2. The criteria defining the components of the index should be clear and understandable to promote accuracy and reproducibility.
3. A severity index should be equally sensitive throughout and should indicate in a meaningful way the clinical stages of the disease.
4. The index should be amenable to statistical analysis.

1.2.4 Categories of Periodontal Disease Indices

Periodontal indices currently in use can be conveniently categorised by the various etiologic factors, clinical signs whether they are reversible or irreversible and the treatment need of the group they purport to measure.

Some indices like the Periodontal Index of Russell and the Periodontal Disease Index of Ramfjord have combined gingival and periodontal scores; while others like the
Gingival Index of Silness and Loe concentrated upon the gingival conditions alone.

Figure 1 summarizes the various criteria which the periodontal indices attempt to measure in either epidemiologic surveys or clinical studies.

Indices measuring etiologic factors of periodontal disease
- Non-mineralized soft deposits
- Plaque
- Oral debris
- Calculus

Indices measuring reversible signs and symptoms of periodontal disease — Gingival health conditions
- Pocket depth measurements
- Tooth mobility
- Radiographic data

Indices measuring irreversible destructive phases of periodontal disease

Indices measuring periodontal treatment needs.

FIG. 1. Categories of Periodontal Indices
2. INDICES FOR MEASUREMENT OF SOFT DEPOSITS

2.1 DIFFERENTIATION OF ORAL SOFT DEPOSITS:

PLAQUE, ORAL DEBRIS, MATERIA ALBA AND PELLICLE.

Plaque can be defined as microbial masses, gel-like mats, organized colonies of micro-organisms closely adherent to the surfaces of teeth or restorations (Mandel 1974). Attachment is maintained despite muscle action, water rinsing or water spray.

Oral debris is particulate matter, mostly food particles and unless mechanically trapped is readily dislodged by lip, tongue and cheek movements and rinsing and is not part of plaque (Mandel 1974). The rate of clearance from the oral cavity varies with the type of food and the individual.

Materia alba is the loosely adherent grayish-white to yellowish mass of bacteria and cellular debris which overlies the plaque, mainly along the gingival margins. It is unorganized and a product of mechanical accumulation. It can be removed by vigorous rinsing or water sprays (Mandel 1966).

Pellicles may be developmental or acquired. In functional teeth, the developmental pellicles are rare.
The acquired pellicle is a bacteria-free film of glycoprotein and lipid derived from the saliva and may cover the entire tooth surface. (Mandel 1974). When covered by bacteria it becomes part of the plaque.

Stains are products of chromogenic bacteria, tars and resin residues from tobacco, reaction of combinations of food components, medications etc. A plaque may be stained, a stain is not plaque.
2.2 INDICES FOR MEASUREMENT OF PLAQUE AREA.

The most common criteria for plaque scoring is the extent of the area occupied. In most instances the area is assigned a number and a numerical index is derived from a mean score per tooth or tooth surface. The teeth examined can vary from full mouth to six selected teeth and to anterior teeth only.

2.2.1 The Plaque Measuring Component

Periodontal Disease Index (PDI, Ramfjord).

The prototype procedure for measure of plaque area was introduced by Ramfjord as part of his Periodontal Disease Index (PDI) (Ramfjord 1959).

Six teeth are measured:
Maxillary right first molar;
Maxillary left central incisor;
Maxillary left first bicuspid;
Mandibular left first molar;
Mandibular right central incisor;
Mandibular right first bicuspid.

Interproximal, buccal and lingual surfaces are examined. Any effective disclosing solution can be used
and is applied to all of the teeth to be examined at the same time. The patient is then instructed to spit and rinse his mouth thoroughly twice.

The scoring is then done according to the following criteria:

0 = No plaque present
1 = Plaque present on some but not all of the interproximal, buccal and lingual surfaces of the tooth.
2 = Plaque present on all interproximal, buccal and lingual surfaces, covering less than one half of the clinical crown.
3 = Plaque extending over all interproximal, buccal and lingual surfaces, covering more than one half of the clinical crown.

Only fully erupted teeth are scored and missing teeth are not substituted. Individual scores for each of the examined teeth are added and divided by the number of teeth examined to give the score.

2.2.2 Ramfjord's PDI, Modified by Shick & Ash.

The Ramfjord PDI was originally designed to screen large populations in epidemiological studies. The plaque
scoring portion is not well suited to clinical studies and has been superceded by the Shick and Ash modification (Shick & Ash 1961).

The modification consists of examining facial and lingual surfaces, but not interproximal of the six selected teeth, and restricting the scoring of plaque to the gingival half of the surfaces.

0 = Absence of dental plaque
1 = Dental plaque at the gingival margin covering less than one third of the gingival half of the facial and lingual surfaces
2 = Dental plaque covering more than one third, but less than two thirds, of the gingival half of the facial or lingual surfaces
3 = Dental plaque covering two thirds or more of the gingival half of the facial or lingual surfaces.

Using the Shick and Ash Index, Rainey and Ash (1964) found that the initial plaque score in their clinical study varied from 0.75 to 1.92. With the upper limit of the score under 2, this observation would appear to validate the use of a scoring technique that accentuates differences in the gingival half of the tooth.
2.2.3 Quigley and Hein Index, Modified by Turesky.

Quigley and Hein also recommended an index that gives greater attention to the gingival third of the tooth (Quigley & Hein 1962). They employed a partial mouth scoring procedure confined only to the labial surfaces of the anterior teeth. Subjects rinsed with 20 ml of a 0.075% basic fuchsin mouthwash and the plaque was recorded as follows:

0 = No plaque
1 = Flecks of stain at gingival margin
2 = Definite line of plaque at gingival margin
3 = Gingival third of surface
4 = Two thirds of surface
5 = Greater than two thirds of surface.

The score was then calculated as the average amount of plaque per tooth surface.

No data of reproducibility have been presented. A difficulty that might arise would be over a distinction between flecks of stain and a definite line of plaque.

Turesky et al (1970) differentiated more clearly the scoring criteria of the Quigley and Hein scale.
0 = No plaque
1 = Separate flecks of plaque at the cervical margin of the tooth
2 = Thin continuous band of plaque (up to 1 mm) at the cervical margin
3 = A band of plaque wider than 1 mm but covering less than one third of crown
4 = Plaque covering at least one third but less than two thirds of crown
5 = Plaque covering two thirds or more of crown.

2.2.4 The Plaque Measuring Component of the Gingival-Periodontal Index (GPI, O'Leary)

O'Leary (1967) recommends a method using Bismark Brown disclosing solution and an explorer in determining the extent of plaque accumulation.

He examines the buccal and lingual tooth surfaces of the entire dentition which was divided into six segments, segmentation being immediately distal of each canine. The highest score of any one tooth in each segment is recorded as the score for the segment.

0 = No plaque on any tooth in segment.
1 = A slight amount of plaque not extending more than 2 mm from the gingival margin on any tooth in the segment.
2 = Plaque covers up to one half of the exposed clinical crown on any tooth in the segment.
3 = Plaque covers more than one half of the clinical crown.

The O'Leary method has been used exclusively for assessment of periodontal health status. It has limited applicability to clinical studies since like PDI scores, it overscores the incisal half of the crown.

2.2.5 Navy Plaque Index Modified by Hancock & Wirthlin.

The original Navy Plaque Index proposed by Elliot, Bowers, Clemmen & Rovelstad (1972) employs a scoring system that gives greater weight to the plaque in the immediate gingival area.

The tooth is separated into three major zones, the occlusal, the middle and the gingival. The gingival zone lies apical to an imaginary line connecting the crests of the interdental papillae and roughly parallels the marginal gingiva, being approximately 1 mm apart from it. This area is again subdivided into a mesial, distal and middle segment. The middle zone lies between the occlusal and gingival zones and is subdivided into the mesial and distal areas.

A score of one is assigned to all areas. More emphasis is thus placed on the plaque adjacent to the
gingival tissues, as the adjacent zones are comparatively smaller in area than either the occlusal or middle zones.

Hancock and Wirthlin modified the Navy Plaque Index by reducing the number of areas to be charted on the tooth and thus simplified the charting procedures (Hancock & Wirthlin 1977).

The small middle gingival area has remained unchanged. The gingival mesial and distal zones now extend incisally up to the respective contact points. The entire remaining tooth surface is now treated as one single area. Facial or lingual surfaces are similarly divided.

Any plaque in contact with the gingival segment is given a score of 2. That in contact with the gingival mesial or distal segment is given a score of 3. Any plaque on facial or lingual surface not in contact with gingival tissues is given a score of 1.

Hancock and Wirthlin found the Navy Plaque Index scores and the gingival scores of the Navy Periodontal Disease Index had a high correlation of 0.75 (P 0.01).
2.2.6 Plaque Area Measurements

Arnim compared the efficacy of various hygienic procedures by determining the total amount of plaque present on the labial surfaces of the four upper and lower incisor teeth (Arnim 1963). Photographs were taken of the tooth surfaces after staining with erythrosin wafers and the Kodachrome transparencies were enlarged four times. The outlines of the respective tooth surfaces and stained masses were traced on paper and their areas determined with a planimeter. The percentage of surface covered by the plaque was calculated.

Kinoshita et al. (1966) modified the Arnim procedure. The colour slides were projected at sixty-five times magnification and the areas of plaque and unstained tooth surfaces traced on paper and cut out for gravimetric determination. The percentage of tooth surface covered by the plaque was then determined.

The disadvantages of intra-oral photographic methods in scoring plaque have been summarized by Grenby (Grenby Bashaara & Gey 1982):

1. It is difficult to ensure all teeth are in focus, properly illuminated and seen from exactly the same angle every time. The problem of camera positioning is increased in dealing with posterior teeth.
2. It can only measure the area of the plaque and not the bulk. This criticism applies not only to photographic methods but in general to all plaque area measurements.

3. The uncertainty of distinguishing areas of plaque from pellicle which is also stained by disclosing solution such as erythrosin.

Stein and Forward (1980) similarly criticised photographic methods but favoured percentage area measurements over plaque indices. They claimed the percentage area measurements can measure plaque on a continuous scale and are sensitive enough to detect small treatment effects. They stained the plaque with erythrosin and used an experienced examiner to draw the outline of stained plaque of the incisors, canines and first molars onto tooth chart diagrams. The areas of plaque were measured using an electronically measuring planimeter.

Bergstrom (1981) used the labial surface of upper lateral incisors and a stereo-photogrammetric method to assess the accumulation of plaque in vivo. The area covered by plaque is given as a percent of the total surface area of the tooth.

He obtained a correlation ranging between $\gamma = 0.66$ and $\gamma = 0.78$ for plaque values from photogrammetry and various other clinical scoring methods. He concludes that
this is a sensitive method for measurements of small amounts of plaque in clinical studies.

Area measurements do provide more quantitative data than numerical indices. They are however much more time consuming. The accuracy and reproducibility of the lingual surfaces and posterior teeth measurements remain to be determined.
2.3 INDEX FOR MEASUREMENT OF PLAQUE THICKNESS:

PLAQUE INDEX (PI, SILNESS & LOE).

An index in which plaque thickness is an important consideration was introduced by Silness & Loe in 1964 and described more fully in 1967. (Silness & Loe 1964; 1967).

The four gingival areas of each tooth: buccal, lingual, mesial and distal, are each given a score from 0 to 3; this is the Plaque Index for the area. The scores from the four areas may be summed and divided by four to give the Plaque Index of the tooth. The Plaque Index for the individual is obtained by adding the scores for all teeth examined and divided by their number.

0 = This score is given when the gingival area of the tooth is literally free of plaque. This surface is tested by running a pointed probe across the tooth surface at the entrance of the gingival crevice. If no soft matter adheres to the point of the probe the area is considered clean.

1 = This score is given when no plaque can be seen by the unaided eye, but when the point of the probe picks up some plaque as it moves across the gingival area of the tooth surface.
2 = This score is given when the gingival area is covered with a thick to moderately thick layer of plaque. The deposit is visible to the unaided eye.

3 = Heavy accumulation of soft matter, the thickness of which fills out the niche produced by the gingival margin and the tooth surface. The interdental area is stuffed with soft debris.

Thus the Plaque Index scores consider only differences as to the thickness of the soft deposit in the gingival area of the tooth surfaces. No attention is paid to coronal extention of the plaque.

Scoring procedures require light, drying of the teeth and gingivae, a mirror and a probe. If optimal conditions and chairside assistance are available, scoring all teeth of an individual requires approximately five minutes.

The Plaque Index can be used in large scale epidemiologic as well as clinical studies, and also within the dentition of an individual.

Recent analyses show no difference in the results when only one of the interproximal surfaces is examined instead of two, provided the score is given double load and then the score for the tooth divided by four.
Ainamo examined the interproximal spaces from both lingual and facial aspects and assigned the greater index value to the mesial or the distal surface (Ainamo 1970).

The following two studies lend support to the validity and reliability of the Plaque Index. Lang et al (1972) found a linear correlation between the index as used on the facial surfaces of anterior teeth and the total area of plaque as measured photographically with sodium fluorescein and a special light. Loesche and Green (1972) reported that unstained Plaque Index scores correlated much higher than stained Plaque Index scores with gingivitis, dry and wet plaque weight.

Shaw and Murray (1975) assessed the inter and intra examiner reproducibility of Plaque Index scores in 203 children. The scores were significantly lower in the second examination compared to the first for both examiners. They concluded that Plaque Index scores cannot be reproduced within a six hour period, but the ranking order of subjects can be maintained. The use of a probe to test for the presence of plaque inevitably disturbs the deposits and can affect the scores of the second examination.
2.4 INDICES FOR MEASUREMENT OF ORAL DEBRIS.

2.4.1 Oral Hygiene Index - Simplified
(OHI-S, Greene & Vermillion)

Several investigators in assessing oral hygiene status use oral debris scores rather than plaque measurements. The widely used Greene & Vermillion Simplified Oral Hygiene Index includes measurement for both oral debris and calculus. The index has been used primarily in epidemiologic surveys where there is no opportunity for rinsing.

The Simplified Oral Hygiene Index is derived from the original Oral Hygiene Index to allow a more rapid evaluation of oral cleanliness in population groups. (Greene & Vermillion 1960; 1968). The Simplified Oral Hygiene Index differs from the original OHI in the number of tooth surfaces scored (six rather than twelve), the method of selecting the surfaces and the scores which can be obtained. The criteria used for assigning scores to the tooth surfaces are similar to those used for the OHI.

The six selected surfaces are:
Buccal surfaces of upper right and left first molars;
lingual surfaces of lower right and left first molars;
labial surfaces of upper right central and lower left central incisors.
A facial or lingual surface is considered to encompass half the circumference of the tooth. A no. 23 explorer is used to estimate the extent of the debris.

0 = No debris or stain present;
1 = Soft debris covering not more than one third of the tooth surface being examined or the presence of extrinsic stains without debris regardless of surface covered;
2 = Soft debris covering more than one third but not more than two-thirds of the exposed tooth surface;
3 = Soft debris covering more than two thirds of the exposed tooth surface.

In clinical trials in which only mouth washes were studied, such a scoring system might be of use. In tooth brushing studies, the areas designated are too gross.

2.4.2 Modifications of Oral Hygiene Index of Greene and Vermillion

(A) Glass (1965) used a modified debris scoring system which could have greater clinical applicability than the OHI-S.

0 = No visible debris;
1 = Debris visible at gingival margin, but discontinuous - less than 1 mm in height.
2 = Debris continuous at gingival margin - greater than
greater than 1 mm in height;
3 = Debris involving entire gingival third of tooth;
4 = Debris generally scattered over tooth surface.

(B) Podshadley and Haley (1968) introduced a modified debris scoring index of Greene and Vermillion, which has applications to clinical testing. Disclosing tablets or erythrosin disclosing solution was used. However the subjects were instructed to expectorate but not rinse out. This can still technically be called a debris index but the difference from a plaque index is slight.

The authors found that the scores were more consistent with this method than with the OHI. The use of disclosing tablets or solution apparently was responsible for the higher degree of accuracy.

(C) Smith and Packer found the six surfaces recommended by Greene and Vermillion were too limited, especially when missing teeth necessitates substitution. (Smith & Packer, 1971). They recommended examination of eight surfaces, one surface being chosen from each of eight clusters.

The clusters suggested are:
1. Maxillary and mandibular facial surfaces.
2. Anterior mandibular lingual surfaces.
3. Maxillary lingual surfaces.
4. Posterior mandibular lingual surfaces.
5. Anterior maxillary lingual surfaces.
6. Anterior mandibular facial surfaces.
7. Anterior maxillary facial surfaces.
8. Posterior maxillary and mandibular facial surfaces.
2.5 PLAQUE WEIGHT DETERMINATION.

Marthaler, Schroeder and Muhlemann (1961) used sandblasted, standardized mylar foils attached to the lingual surfaces of lower anterior teeth as a means of measuring total plaque weight. After exposure to various clinical situations, the foils were dried at 110°C and weighed. The deposits were removed chemically, the foils redried and reweighed. This is a time consuming procedure best suited to pilot studies but with limited applicability to general clinical testing.

Removal of plaque directly from tooth surfaces and subsequently weighing it is less precise but simpler than the foil technique.

Caldwell et al (1970) scraped the plaque from six tooth surfaces as prescribed by Greene and Vermillion after a one week period. The plaque material was dried overnight at 85°C and weighed.

Lobene (1970) scraped the buccal and lingual surfaces of maxillary right central, first premolar and molar after a three day period and dried the plaque at 105°C for 24 hours. He compared the plaque weight to plaque index scored by the Quigley and Hein method and found a poor correlation.
Loesche and Green (1972) examined plaque using both wet (chairside weighing within one minute) and dry weight (at 95° constant weight). They found wet weight to be the preferred measurement for estimating plaque mass because it was easier to obtain. The wet weight also correlated closely with the unstained plaque score and showed a higher correlation with gingivitis scores than the dry weight. The correlation of both wet and dry weight with stained plaque scores were poor, a finding similar to that reported by Lobene.

It appears that measurements assigned to the stained areas frequently include a considerable amount of pellicle which would increase the numerical area score but have little effect on weight.

Grenby et al (1982) used a combination of visual examination, photograph-grid scoring and plaque dry weight methods in comparing the effects of xylitol and sucrose chewing gum on dental plaque growth. No consistent difference between the two types of chewing gums was found when using either the plaque score per tooth or the grid scoring method. However xylitol chewing gum was found to be associated with a significant reduction of plaque growth compared to sucrose when the plaque dry weight method was used.

Lobene (1970) suggested that in small samples of subjects, the dry weight method was sensitive enough to detect thick heavy plaque confined to small areas on the tooth surface that would otherwise be missed if only plaque indices were used.
2.6 LABORATORY ANALYSIS

The plaque dry weight is composed of carbohydrate-nitrogen and inorganic materials. In several studies chemical assays were performed to measure carbohydrate and nitrogen contents of plaque. Loesche and Green (1972) found that carbohydrate and nitrogen contents correlated poorly with plaque dry weight and gingivitis scores.

They also investigated microscopic counts of dispersed plaque and showed that they correlated highly to plaque weight and gingivitis scores. This measurement is too time consuming and error prone to be a routine procedure. The turbidity or the absorbance of plaque suspension readings are simpler and quicker and have higher correlation with plaque weight. Large numbers of samples can be processed at the convenience of the investigator.

Mandel (1974) recommends that plaque wet weight and absorbance measurements should be considered as objective measurements of plaque.

Chemical analysis seems to be more appropriate for determining plaque pathogenic potential rather than the general amount of plaque. Recent studies on microflora associated with periodontal lesions have found a predominance of gram negative rods which are mainly asaccharolytic (Socransky 1979; Griffe, Patterson, Miller Katrawy & De Obarrio 1982).
The cytotoxic and antigenic substances of these gram negative anaerobic rods and their endotoxin in particular, have been implicated as important factors in pathogenesis of chronic periodontal disease (Aleo, De Renzis, Farber & Varboncoeur 1975; Simon, Goldman, Ruben & Baker 1970, 1971, 1972).

Fine, Tabak, Oshrain & Salkind (1978b) defined a technique for the positive identification of endotoxin in heterogeneous plaque samples. They modified the limulus lysate assay (Shapiro, Lodato, Courant & Stallard 1972; Johnson, Chen, Nowatry & Dombrowski 1976) to measure exclusively the activity of the gram negative bacterial cell wall fraction in which the endotoxin resides. This method is useful in evaluating the effectiveness of chemotherapeutic agents in the reduction of plaque endotoxin.
2.7 DISCLOSING AGENTS

Plaques are usually colourless and hence most of the scoring techniques employ a disclosing solution to visualize the deposits.

Commonly used agents are Bismark Brown, basic fuchsin, F.D.C. red No. 3 (erythrosin), F.D.C. green No. 3 (fast green, brilliant green), the two tone dye (a combination of erythrosin and fast green) and F.D.C. yellow No. 8 (fluorescin). Any dye for the purpose of disclosing plaque must not be toxic or permanently stain the tissues (Mandel 1974).

Some early studies suspected fuchsin to be carcinogenic. Arnim introduced erythrosin in 1963 (Arnim 1963). It is very convenient to use in its commercial tablet form. It is however, non-specific and stains oral mucosa, pellicle as well as plaque. Its prolonged and intensive stain can be objectionable to some users. Also it has been reported to be antimicrobial (Beugue, Bard & Kohene 1966) although Goldman et al (Goldman, Ableson, Mandel & Chilton 1974) found no such evidence.

A fluorescent dye technique, the Plak-Lite System, was developed by Brilliant for disclosing dental plaque (Lang, Ostergaam & Loe 1972). The dye is only discernable when made to fluoresce by exposure to a special light source using a dichroic filter. Squillaro, Cohen & Laster (1975) reported its distinct advantages over
erythrosin in its ability to expose soft tissue plaque and be invisible in day or room light.

In a study of the differentiated staining properties of erythrosin and fluorescin, Gillings (1977) noted that erythrosin stained all visible surface deposits whereas fluorescin stained only old established plaque. In the Block two tone dye system, the erythrosin stains all surface deposits red, while the counter dye, F.D.C. green No. 3, apparently stains only old mature plaque. The combined effect of red and green produces a blue stain. (Block, Lobene & Derdivanis 1972). However, no disclosing agent at the present can differentiate between plaques that are highly pathogenic versus plaque that may have been modified by a chemical agent in clinical studies.

Loesche and Green (1972) indicated that unstained plaque scores correlate better with gingivitis and plaque weight than stained scores using Bismark Brown. The inaccuracy is derived from the inability of the stain to differentiate pellicle from plaque. Hence the convenience of a disclosing agent may be at the expense of accuracy when the index is to be related to gingivitis and not only to plaque control procedures.
2.8 CRITERIA FOR SELECTING AN INDEX FOR MEASURING SOFT DEPOSITS.

2.8.1 Epidemiologic Studies

Epidemiologic studies are primarily for the purpose of disclosing differences in prevalence, severity and for associating the presence or absence of the disease with specific agents and factors.

Greene (1959) listed the characteristics of an index suitable for plaque or oral debris measurements in epidemiologic studies.

1. The method of choice must have definite scoring criteria which reduce examiner decisions to a minimum.
2. Periodontal specialists or original researchers of the index in use are rarely available for extensive field work. The techniques to be employed must be simple to apply and within the abilities of those using them.
3. Speed of application is preferred to sensitivity in measuring small differences. The scales of the scoring system thus need not be as refined as those designed for experimental clinical trials.
4. The method however must be sufficiently quantitative to provide a measure of the degree of severity and the final score can be analysed statistically.
5. Epidemiologic studies usually involve examinations from several investigators and their results compared.
Inter and intra examiner errors are of primary concern and must be reduced to a minimum.

In the late 1950's and early 1960's, the Ramfjord PDI and Greene and Vermillion's OHI-S were developed to study the incidence of periodontal disease and the oral health status of various populations respectively.

Both of these indices have a plaque or oral debris scoring component which fulfills the criteria listed by Greene.

Both indices were extensively used by investigators on a world-wide basis and extensive data are available concerning examiner reproducibility.

The Greene and Vermillion OHI-S does not require the use of a disclosing agent or rinsing and is the most appropriate measure for oral hygiene status.

Greene reported the percent of intra-examiner agreement between the first and second score on 550 tooth surfaces examined were:

Debris : 84
Supragingival calculus : 95 and
Subgingival calculus : 81 (Greene 1967).
The inter-examiner agreement was reported to be less than that of the intra-examiner agreement. Standardization or calibration of examiners in training programs is essential. He also advocated the use of a disclosing agent in training sessions to avoid disturbing the debris with the explorer.

The recent WHO (1979) publication of "A Guide to Oral Health in Epidemiological Investigations" recommended the OHI-S for measurement in large populations.

2.8.2. Clinical Studies

The selection of a particular index for measuring soft accumulations on the teeth in clinical studies according to Mandel (1974) should relate to:

1. The nature of the agent;
2. The procedure to be tested, and
3. The objective of the study.

In general, the objectives of using such indices in periodontal clinical studies would be:

1. Measurement of cleaning efficiency per se such as in mechanical removal of soft deposits;
2. Relation of the deposits to gingival health;
3. Measurement of plaque formation under certain specified
conditions or procedures such as in mouth wash studies in absence of oral hygiene.

2.9.2.1 Numerical Indices

The numerical indices discussed can be classified into three categories: those that do not differentiate between gingival one third and coronal deposits in scoring, those that place more weight on the gingival deposits and those which only consider gingival deposits.

In the first category are the original Ramfjord PDI and the OHI-S. The areas designated are all rather gross and any amount of gingival deposit is only assigned a score of 1 on the 0-3 scale.

These indices can only offer a gross estimation of plaque in large population groups where the effect on gingival inflammation is not a main concern. The scoring range would have serious limitations in a dentifrice study where even the most haphazard brushing would be apt to remove plaque from the incisal half of the teeth. It has application in a non-brushing mouth rinse study. But even in such a study, only 15 percent of subjects in the non-brushing control group scored above 2 on a scale based on the OHI-S (Stallard, Volpe, Orban & King 1969).
The criticism of inadequate attention to the differentiation of degree of plaque accumulation in the gingival area led to modifications of these indices or formulations of new ones for clinical study uses.

The Ramfjord index modified by Shick and Ash belongs to the second category of indices. It uses the same six teeth selected by Ramfjord but confines scoring to the gingival half area of the tooth. Posterior and anterior teeth are included in the cluster and the results could be extrapolated to a total mouth evaluation.

The Quigley Hein Index as modified by Turesky using a scale of 0-5 further emphasizes differences in plaque accumulation in the gingival one third of the tooth. Gingival deposits are scored on clearly outlined criteria of flecks, continuous band and band width. The weighting of score to differentiate relative subtle amounts of plaque along the gingiva enables it to reflect the realities of the plaque - gingival inflammation relationship rather than just aesthetic considerations.

The partial mouth scoring in the original Quigley Hein procedure would not be as efficacious since it only involves labial surfaces of anterior teeth. The Turesky modification used a full mouth scoring. However a partial mouth scoring with inclusion of posterior teeth and lingual surfaces will be more accurate and not overly time consuming.
At the other extreme is the Silness Loe Index which only measures accumulations at the gingival crescent. In this system a value of 2 is given to a thin to moderate layer of material and a value of 3 to a thick layer.

A series of studies on the development of experimental gingivitis (Thelaide et al 1966) and the effect of chlorhexidine on gingivitis (Loe et al 1976) attest to its applicability for evaluating oral hygiene.

The major problem with the Plaque Index is how different investigators would differentiate a moderately thick (score 2) to a heavy layer (score 3) of plaque.

The Silness Loe Index after examiner standardization should be a useful technique for evaluating anti-plaque agents and procedures. A measurement of thickness rather than area is more meaningful in the pathogenesis of gingival disease.

2.8.2.2 Total Area Measurements

Bergstrom (1981) studied the rate of accumulation of plaque in vivo. Plaque tends to build up from the gingival area to the occlusal surface. A continuous band of plaque along the gingival border was evident after abandoning oral hygiene measures for five days. At ten
days small flecks coalesced to form larger areas and the width of the gingival band increased. The plaque thickness at the gingival margin continued to increase towards the 20th day. However he noted that plaque on prominent earlier covered areas on the tooth surface were seen to be torn off.

Gottsegen (1974) reported that in plaque accumulation after fifteen days the occlusal portion of the plaque in some patients were knocked off from the buccal and lingual surfaces. It seems that mastication is an important variable in affecting surface area measures.

However limiting measurement of plaque to gingival margin only is not adequate in measuring the ability of an agent to remove or prevent TOTAL deposits, particularly in populations of heavy plaque formers.

Total area measurements of plaque are subject to substantial error whether the disclosed plaque is recorded by camera or drawn on standardized tooth charts by experienced examiners. It is not known if the errors are greater than those of a numerical index. In view of the paucity of data on accuracy and reproducibility the lack of data on lingual surfaces and posterior teeth and the considerable time and effort involved, total area measurements appear to have very limited applications to clinical studies involving an appreciable number of subjects.
Volume or thickness of plaque is more important than pure area measurements in the plaque gingivitis relationship.

2.8.2.3 Plaque Weight Measurements

The chief advantage of plaque weight measurements is that it is more objective. However, there is uncertainty in the technique of complete removal of the plaque. It is also necessary to define whether the plaque is collected just up to the gingiva or below the gingiva and whether buccal, lingual or interproximal plaque are included.

One of the major disadvantages of the plaque weight procedure is that daily measurements in individual subjects are not possible. Once the plaque is scraped off, at least three days must elapse before sufficient material accumulates for further weighing. A reasonable combination would be visual examination during the experimental period followed by plaque removal for weighing at the end of the period.

2.8.2.4 Pathogenic Potential Measurements

Gottsegen (1974) suggested that the pathogenic potential of plaque is as important as the volume and
rate of its formation in periodontal disease.

Mackler and Crawford (1973) in a three week study of no oral hygiene routine in three-year-old and five-and-a-half year-old children found there was development of plaque and complex flora with no subsequent gingivitis.

Loe, Theilade & Jensen (1965), in experimental gingivitis in man, found that all subjects began to develop some evidence of gingivitis by 21 days in the absence of oral hygiene.

The variation in the biological and chemical nature of plaque for different age groups calls for further investigation (Spencer, Beighton & Higgins 1983).

Fine et al (Fine, Tabak, Oshrain, Salkind & Siegel 1978a) reported that loosely adherent plaque collected from periodontal pockets had a higher mitogenic and pyrogenic activity than adherent plaque collected supragingivally. This is in spite of the fact that the mass for adherent plaque was four to five times greater than loosely adherent plaque. Methods for measuring pathogenic potential of plaque in terms of plaque pH, specific organisms, enzymes or toxins would represent a whole new area for clinical testing. However, total removal of plaque is still the best means of plaque control since no single organism or substance in plaque has been
established as the sole causative factor in periodontal disease. Hence, all indices measuring the amount of plaque and debris present on a tooth will continue to serve useful purposes in plaque control studies.
3. INDICES FOR MEASUREMENTS OF HARD DEPOSITS

3.1 DENTAL CALCULUS AND ITS ROLE IN GINGIVITIS AND PERIODONTAL DISEASE.

Schroeder (Schroeder 1969) defined supragingival dental calculus as mineralized plaque and/or material alba permeated with crystals of various calcium phosphates which occurs above the gum margin as white-yellow and moderately hard deposits. Very often they are covered by vital non-mineralized plaque. Supragingival calculus occurs most frequently and in the greatest quantity on the buccal surfaces of the maxillary molars opposite Stensen's duct, the lingual surfaces of the mandibular anterior teeth opposite Wharton's duct and more on the central incisors than on the laterals (Turesky, Renstrup & Glickman 1967).

Subgingival dental calculus is defined as the calcified organic matrix of microorganisms and inter-microbial matrix occurring below the crest of the marginal gingiva, usually in chronically inflamed environment such as periodontal pockets (Schroeder 1969). It is very hard and often stained dark brown to green black. It may be invisible upon oral examination. Determination of the location and extent requires careful probing with an explorer. It is firmly attached to the tooth surface.
Dental calculus is known to play an important role in the etiology of periodontal disease (Parfitt 1959; Ramfjord 1961; Schroeder 1965). However it is neither necessary nor sufficient for gingivitis or periodontal disease (Zimmerman 1974). Plaque is more important in the initiation and maintenance of gingivitis (Hoover & Robinson 1962; Ramfjord 1961). In a study of 300 subjects Buckley (1980) reported that the Gingival Index correlated much stronger to plaque than to calculus. Gingivitis occurs in the absence of calculus (Marshall-Day & Shourie 1950) and the formation of plaque leads to gingivitis which disappears when the plaque is removed (Theilade, Wright, Jensen & Loe 1966; Shei, Waerhaug, Lovdal & Arno 1959). However it is difficult to separate the effects of calculus and plaque upon the gingiva, because the surface of calculus is always covered with viable plaque (Schroeder 1965).

In contrast to plaque, data of almost all investigation indicate the intensity of dental calculus increases with age (Greene & Vermillion 1964; Lilienthal Amerena & Gregory 1965; Ramfjord 1961). This appears to be due to simple prolongation of the accumulation rather than to an enhanced ability to form calculus (Schroeder 1969).

Regardless of its primary or secondary relationship in periodontal disease, calculus correlates positively
with periodontal disease though to a lesser extent than plaque (Ramfjord 1961; Silness & Loe 1964). It provides a rough surface for the continuous accumulation of plaque and holds plaque against the gingiva. (Allen & Kerr 1965). Its diagnosis and complete removal are essential in any form of periodontal disease treatment.
3.2 **EPIDEMIOLOGICAL INDICES**

In the late 1950's and early 1960's, two indices were developed to study the incidence of periodontal disease and the oral health status of various populations. These indices, both of which contain calculus quantitating components, were the Ramfjord's Periodontal Disease Index and the Greene and Vermillion's Oral Hygiene Index.

Since their introduction, they have been widely used by investigators on a world wide basis and extensive data are available concerning examiner reproducibility. Although they have been used almost exclusively in epidemiological surveys, some calculus clinical studies have been conducted using their calculus quantitating components.

3.2.1 *The Calculus Component of Periodontal Disease Index (PDI, Ramfjord).*

The calculus index component of the Periodontal Disease Index utilizes the following six selected teeth (Ramfjord 1959):

- The maxillary right first molar;
- The maxillary left central incisor;
- The maxillary left first bicuspid;
- The mandibular left first molar;
The mandibular right central incisor;
The mandibular right first bicuspid.

Calculus is diagnosed at the periphery of the tooth with a dental explorer and is scored on the four surfaces of the six selected teeth according to four grades of severity. Subgingival calculus is given a greater score. The four severity grades are as follows:

0 = Absence of calculus;
1 = Supragingival calculus extending only slightly below the free gingival margin (not more than 1 mm);
2 = Moderate amount of supragingival and subgingival calculus or subgingival calculus alone;
3 = An abundance of supragingival and subgingival calculus.

The scores for calculus for each of the six selected teeth examined are added and the sum divided by the number of teeth examined to provide a subject's index for calculus.

In a later report Ramfjord (1967) noted that subgingival calculus can be located with a No. 17 probe when there is uncertainty using the University of Michigan No. 0 probe. Also it was stated that the PDI was modified without a loss in accuracy to include an evaluation of only the buccal and mesial surfaces of the six selected teeth.
3.2.2 The Calculus Component of Oral Hygiene Index - Simplified (OHI-S, Greene & Vermillion)

The calculus component of the Oral Hygiene Index - Simplified (Greene 1967) uses the following six selected tooth surfaces: buccal surface of the first fully emptied maxillary tooth distal to the second bicuspid (left and right sides); lingual surface of the first fully erupted mandibular tooth distal to the second bicuspid (left and right sides); labial surfaces of the upper right central incisor and the lower left central incisor.

A No. 23 dental explorer is used to estimate the surface area covered by supragingival calculus and to probe for subgingival calculus. Calculus scores are assigned according to the following criteria:

0 = No calculus present;
1 = Supragingival calculus covering not more than one third of the exposed tooth surface being examined;
2 = Supragingival calculus covering more than one third but not more than two thirds of the exposed tooth surface, or the presence of individual flecks of subgingival calculus around the cervical portion of the tooth;
3 = Supragingival calculus covering more than two thirds of the exposed tooth surface, or a continuous heavy
band of subgingival calculus around the cervical portion of the tooth.

The OHI-S was developed to reduce both the number of decisions required on the part of the examiner and the time required for the evaluation. The OHI-S uses six tooth surfaces while the basic OHI uses twelve.

The total calculus scores obtained from a subject are divided by the number of teeth surfaces scored to determine a subject's Simplified Calculus Index (CI-S).

Greene (1967) indicated that if surveys are conducted on a relatively small group (such as short term clinical studies), variations of the OHI-S are available. These variations in the Calculus Component include:

1. Calculus scores can be assigned to more or all tooth surfaces.
2. Supragingival calculus can be recorded separately.
3. The subgingival calculus portion can be divided into three categories, instead of two. This might be done by giving a score of 1 when the subgingival calculus extends less than one third of the way around the tooth, and a score of 2 when it extends more than one third but is not continuous. A score of 3 can be given if it forms a continuous band around the surface being examined.
3.3 INDICES FOR CLINICAL CALCULUS STUDIES

3.3.1 Early Clinical Methodology

The early clinical calculus studies from mid-1940's to the late 1950's were conducted to evaluate the effect of calculus inhibiting materials utilized. These were mostly clinical impressions obtained from a direct visual examination (Kerr & Field 1944; Grossman 1954), or through use of intraoral photographs (Jensen 1959).

These techniques were basically rapid and subjective (or in some cases semi-quantitative). estimations of the absence of presence and/or the amount of calculus that had accumulated. Little effort was directed towards the establishment of examiner standardization and reproducibility procedures.

3.3.2 Recent Clinical Methodology

During the decade from 1960 to 1970, a considerable clinical research effort was expended in developing calculus quantitating procedures that were as objective, quantitative and reproducible as possible. Three major quantitating procedures for the direct in vivo measurement of calculus deposits were introduced.
The three methods were the Calculus Surface Index (and its companion Calculus Surface Severity Index), the Probe Method of Calculus Assessment and the Marginal Line Calculus Index. Additionally, one method was developed which permitted the indirect evaluation of calculus deposits. This method was the Standardized Foil Technique.

All four procedures were developed for the clinical evaluation of calculus inhibitory materials or formulations.

3.3.2.1 Calculus Surface Index

(CSI: Ennever, Sturzenberger & Radike).

The Calculus Surface Index (CSI) method uses the four mandibular incisor teeth in the evaluation of calculus accumulations (Ennever, Sturzenberger & Radike 1961). The selection of these teeth was based upon the rate of calculus formation and the ease of observing calculus on these teeth.

Calculus was considered to be present if any amount, supragingival or subgingival, could be detected either visually or by touch. If the examiner was uncertain about the presence of calculus on a given surface, the surface was called calculus free. Each subject was examined through use of a No. 23 dental explorer and a mouth mirror.
Four surfaces of each of the mandibular incisor were considered: two proximals scored from the lingual aspect, one labial and one lingual. At examination a number of surfaces on which calculus had occurred were scored for each tooth. The total number of surfaces (total number of 16) on which calculus was detected is the subject's calculus score and is referred to as the Calculus Surface Index (CSI).

The Calculus Surface Severity Index (CSSI) is a measure of the quantity of calculus present on the labial, lingual, mesial and distal of the four mandibular incisors (Ennever et al 1961; Conroy & Sturzenberger 1968).

Calculus is assessed on a severity scale from 0 to 3 on each of the four surfaces of the mandibular incisors (maximum possible score of 48). The scoring scale is as follows:

0 = No calculus present;
1 = calculus observable, but less than 0.5 mm in width or in thickness;
2 = Calculus not exceeding 1 mm in width or thickness;
3 = Calculus exceeding 1 mm in width or thickness.

The CSI method has been shown to have excellent
inter-examiner reproducibility and to be a relatively rapid and efficient scoring procedure for calculus deposits. (supragingival or subgingival) (Ennever et al 1961).

It is particularly advantageous in evaluating calculus deposits that have accumulated over a relatively short period of time (1 to 6 weeks). The CSI can be modified to include all natural teeth that are present and a clinical study has indicated that partial mouth calculus scores are correlated with corresponding whole mouth calculus scores (Alexander 1970).

Additionally, two calculus clinical studies have indicated that comparable calculus reductions can be obtained when using either the CSI or CSSI on either a partial mouth or full mouth examination basis (Sturzenberger, Swancar & Reiter 1971; Conroy, Sturzenberger, Bollmer, Swancar & Zimmerman 1972).

3.3.2.2 Probe Method of Calculus Assessment
(Volpe and Manhold).

The Probe Method of Calculus Assessment was developed over a seven year period (1960-1967). The first publication concerning this technique was a preliminary report which described a method of evaluating the effectiveness of potential calculus inhibiting agents
This method was further developed and refined over the next three years and more thoroughly described in a subsequent publication (Volpe, Manhold & Hazen 1965). It presented inter-examiner reproducibility data obtained from a three month clinical study, and provided a modification of the original technique. It measured calculus in three constant planes instead of one vertical plane obtained by bisecting the mandibular incisor tooth with a periodontal probe.

The three measurement planes for the quantitation of calculus accumulations on the lingual surfaces of the mandibular six anterior teeth are as follows:

1. The first plane is for gingival measurements and is obtained by vertical positioning of the probe so as to bisect the lingual or facial surface of the tooth.
2. The second plane is for distal measurements and is obtained by positioning the probe so as to bisect the mesial-incisal angle of the tooth and then placing the probe diagonally through the area of greatest calculus width on the distal aspect of the tooth.
3. The third plane is for mesial measurements and is obtained by positioning the probe so as to bisect the distal-incisal angle of the tooth and then placing
it diagonally through the area of greatest calculus width on the mesial aspect of the tooth.

With three measurement planes and a maximum height of 3 mm for the calculus width on a tooth, each tooth could then have 9 calculus units for a total possible score of 54 units for the six teeth.

Fischman and Picozzi (1969) proposed to standardize and clarify the reporting of calculus scores with the Probe Method. The proposed scoring methods were as follows:

1. Per measure score - the total of the individual measurements divided by the number of measurements made (usually 18).
2. Per tooth score - the total of the individual measurements divided by the number of teeth scored (usually 6).
3. Per subject score - the total of the individual measurements (each subject must have all six teeth present).

Mulhemann (1968) in using the Probe Method in calculus study had recommended that the initial score of 0.5 units be assigned to any calculus present, even before it has reached 0.5 mm in height. Thus the Probe Method would be based, for the earliest stages of calculus formation, on the presence of absence alternative,
and later on the calculus growth measurements.

Volpe et al (Volpe, Kupczak & King 1967) in a later report described the probe calibration, examiner training and proper examination in detail. The proper positioning of the periodontal probe is graphically illustrated as in Figure 2.

Volpe et al (Volpe, Kupczak & King 1969) in a different report presented data which demonstrated a significant correlation between the partial and full mouth examinations of calculus scores by the Probe Method and a high degree of intra-examiner reproducibility.

In two independent studies, two Probe Method calculus scores correlated strongly with the dry, ash and organic weights of the removed calculus. (Sharawy, Sabharwal, Socransky & Lobene 1966; Piccozzi 1971).

FIG. 2. Graphic illustration of the proper positioning of the probe as used in the Probe Method of Calculus Assessment. (Illustration reproduced from Volpe, Kupczak & King 1967).
Fischman & Picozzi (1970) also found a clinical correlation between the Probe Method and Gingivitis scores using a modified Periodontal Index by Russell.

In another study, the dry weight of carefully removed calculus specimens and gingivitis scores as determined by Gingival Index of Loe highly correlated with the mean calculus scores as determined by the Probe Method (Fischman 1970).

In two additional studies, calculus reductions obtained with the Probe Method were comparable to those obtained through use of the CSI and the CSSI. (Sturzenberger et al 1971; Conroy et al 1972).

In summary, the Probe Method of Calculus Assessment is an acceptable method for quantitating supra-gingival calculus deposits, especially over long periods of time. It possesses a high degree of intra-examiner and inter-examiner reproducibility. It correlates with calculus dry weight and gingivitis scores and is relatively simple to use. However Volpe suggests that it takes a minimum of 30 to 50 examinations under the guidance of an experienced investigator to familiarize a new examiner with the Probe Method (Volpe 1974). Also it is not exceptionally rapid to conduct, taking 5 to 10 minutes to complete.
3.3.2.3. *Marginal Line Calculus Index*  
*(MLC, Mulhemann & Villa)*.

The Marginal Line Calculus Index was developed in order to provide an accurate measurement of supragingival calculus accumulations which is in the area of closest proximity to the gingiva. Thus the rate of calculus formation can be more precisely correlated to inflammatory gingival disease (Mulhemann & Villa 1967).

The MLC Index only scores supragingival calculus formed in the cervical area along the marginal gingivae on the lingual side of the four mandibular incisors. For better precision in scoring the cervical bank along the gingiva of the tooth is divided into two parts by an axial plane which bisects the incisal edge by the incisors which is directed towards the most apical position of the gingival margin. The resulting mesial and distal part of the band or line are scored separately by estimating the percentage of the distance covered by the calculus deposits.

In order to simplify the procedure, only 0, 12\(\frac{1}{2}\), 25, 50, 75 and 100 percentages are used. The smallest calculus score is 12.5 percent. If the examiner is uncertain about the percentage to give, the higher percentage is assigned. The mesial and distal percentages per tooth
are averaged. The means of the four teeth are averaged to give the subject's score, the maximum possible being 100 percent. This procedure is diagrammatically illustrated in Fig. 3.

<table>
<thead>
<tr>
<th></th>
<th>DISTAL</th>
<th>100</th>
<th>25</th>
<th>50</th>
<th>75</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>MESIAL</td>
<td>100</td>
<td>75</td>
<td>25</td>
<td>0</td>
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<tr>
<td>TOOTH</td>
<td>AVERAGE</td>
<td>100</td>
<td>50</td>
<td>37.5</td>
<td>37.5</td>
</tr>
</tbody>
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Subject score  
\[ = 56.25 \]

FIG. 3. Diagrammatic representation of the scoring procedure utilized in the Marginal Line Calculus Index. This illustration was reproduced from Mulhemann & Villa 1967.

Since minute particles of calculus are not visible when wet, total dryness of the lingual cervical area is essential for scoring. The time needed to score four incisors is approximately five minutes, since great care is necessary for the detection of these minute calculus deposits.
The MLC Index has been used in a clinical study and has been shown to have excellent inter-examiner reproducibility (Mulhemann & Villa 1967). Another investigation was conducted to compare the MLC Index with several other calculus quantitating procedures in short term as well as long term evaluations of a calculus inhibiting material (Villa, Brakas & Mulhemann 1967). The other methods evaluated were the Calculus Surface Index, the Probe Method of Calculus Assessment and the Standard Foil Technique.

The resulting calculus reduction data varied to a considerable extent, probably due to (1) the diagnostic criteria "presence of calculus", (2) the procedures associated with calculus scoring, (3) the inhibitory effect of the agent on calculus deposits and (4) the length of the study.

The comparative effect of tooth brushing on calculus formation was investigated in another study. The MLC Index was compared with the Probe Method of Calculus Assessment and the Calculus Surface Index. All three indices provided a reduction in calculus formation attributable to habitual and individual tooth brushing. The reduction was greatest with the Probe Method and least with the CSI.
In summary, the Marginal Line Calculus Index appears to be an acceptable method for quantitating early supragingival calculus formation (1 to 20 weeks) in close proximity to the gingival tissues. It has a high degree of inter-examiner reproducibility. It similarly requires the examiner to be highly trained and very conscientious.

3.3.2.4 Standardized Foil Technique (Marthaler, Schroeder & Mulhemann)

The "Strip Technique" evaluation of calculus was initially developed in 1957 for the histochemical analysis of calculus formation (Mandel, Levy & Wasserman 1957).

The basic principle of the strip technique was used in the development of a new indirect method which provided for the quantitative assessment of calculus deposits. It was primarily developed to study supragingival calculus formation under natural conditions and to test potential calculus inhibitors (Marthaler, Schroeder & Mulhemann 1961).

Standardized triangular and round edged foils approximately 29 mm are punched out of sandblasted polyester sheets (Mylar, Dupont Type A200). The foils
are perforated and attached to the lingual surfaces of lower central incisor teeth by means of nylon thread. The foils are dried for three hours at 110°C, cooled in a dessicator and weighed before application to the teeth. After removal from the teeth, the foils are reweighed with their deposits.

Repeated measurements of dry weight of deposits obtained from the foils attached on lower central incisors remain in the same proportion, indicating excellent reproducibility for this technique.

Although this technique was basically developed to collect supragingival calculus, it can readily be adapted to extend into the sulcular area and collect subgingival calculus.
3.4 CRITERIA FOR SELECTING AN INDEX MEASURING HARD DEPOSITS.

3.4.1 Epidemiological Surveys.

Both the PDI and the OHI-S calculus components have been used extensively in epidemiological surveys and there is a considerable amount of clinical data available concerning examiner reproducibility of the indices.

Both place scoring emphasis on subgingival calculus. For the PDI, moderate deposits are given a score of 2 and an abundant deposit a score of 3. All interproximal buccal and lingual surfaces are examined for the six index teeth.

The OHI-S uses more exacting criteria (coverage of one third or two thirds of the surface examined) and only examines one surface of each of the six index teeth. Each surface is considered to encompass half of the circumference of the tooth.

Trained examiners can conduct an accurate quantitation of calculus deposits in a relatively short period of time. The OHI-S with less surfaces to examine is the quicker of the two methods.
Greene (1968) assessed the sensitivity of the OHI-S using the six surfaces method and compared the results obtained using the twelve surfaces method of the original OHI and the all surfaces method.

He found the OHI-S using six surfaces tended to underscore in the low ranges and overscore in the high ranges. The apparent contradiction in the sensitivity of the OHI-S stems from the system of selection of six surfaces to represent the whole dentition.

These surfaces are: the buccal of upper left and right first molars, the lingual of lower left and right first molars, the labial of the upper right central and the lower left central.

The calculus and debris on the lingual surfaces of anterior teeth often present even in relatively clean mouths are not scored with the six surfaces method. This results in underscoring.

The six surfaces nonetheless are sensitive indicators of the overall status of oral deposits. There is a greater chance of obtaining low mean scores for all surfaces than when examining only these six surfaces. Thus overscoring in the high ranges is quite possible with the six surfaces method.
Both the PDI and the OHI-S have good reproducibility in the hands of trained examiners. The OHI-S calculus scoring scale has defined its criteria in more exacting terms than that of the PDI. If the selection of tooth surfaces for the OHI-S can include lingual surfaces of anterior teeth, its sensitivity can be enhanced. However for epidemiological purposes, the present OHI-S is quite adequate and still the index of choice.

3.4.2 Clinical Studies

The specific recommendation of a particular calculus quantitating index will depend on the purpose and design of the clinical study, the size of the population sample, the period of study and the type and extent of changes anticipated.

The clinical evaluations of agents or formulations for their calculus inhibitory effects can be arbitrarily divided into two basic classifications: short term screening procedures (pilot studies) and long term clinical studies.

The time factor together with the design of the study will determine the characteristics of the calculus deposits to be encountered:
1. Location - predominantly anterior teeth, posterior teeth or both; proximity of calculus to gingival tissues;
2. Type - predominantly supragingival, subgingival or both.
3. Quantity - "flakes", "specks" or large solid areas.

When these characteristics are established, the investigator can intelligently select that index which will most accurately quantitate the particular calculus deposits that he anticipates encountering in his particular clinical calculus study.

The index must also possess the following two important properties:

1. It has demonstrated examiner reproducibility;
2. It has been previously used in clinical investigations, thus providing a source of reference data for future clinical investigations.
3. The clinical scores correlate with dry weight of calculus.
4. It can detect small amounts of calculus. This is of great importance in short term studies.

Prior to beginning a clinical trial, either short term or long term, a standardization period for the examiner is mandatory, to be certain that he is applying the index in the same manner as previous investigators. The investigator should be calibrated through the use of
approximately 30-50 preliminary examinations, preferably under the supervision of an experienced investigator (Volpe 1974).

Whenever the conditions permit, it is always useful and desirable to obtain standardized intra-oral photographs or slides to supplement whatever calculus quantitating procedure is being used.

If more than one examiner is used, comparability of scoring criteria must be demonstrated by having each examiner perform replicate examinations of a small group of subjects. An estimate of inter-examiner error can be obtained.

In reported studies (Picozzi, Fischman, Pader & Cancro 1972; Fischman & Picozzi 1970; Fischman 1970), the reviewer and his co-workers demonstrated the desirability of including a "placebo group" in clinical trials. The reduction in calculus scores seen in groups using placebo products is clinically important and may approach statistical significance. The true efficacy of a therapeutic agent can probably best be described as the "net" difference between the decrements in scores of the placebo group and the experimental group when compared to comparable base-line measurements.
The investigation should acquire and use the specific equipment that the method requires, whether it be special periodontal probes or standardized foils.

An adequate lighting source is always useful. A good and reliable source of air to dry the deposits prior to scoring absolutely necessary. An assistant should be available to make the recordings so that the investigator can devote his full attention to the quantitating procedure.

3.4.2.1. Short Term Screening Procedures

The short term screening procedures are usually conducted in a period of time ranging from 1 to 5 or 6 weeks.

A relatively small number of subjects is used to evaluate the effectiveness of several materials in vivo in respect to their ability to inhibit the formation of supragingival and subgingival calculus.

These short term procedures are the so-called "decision making procedures", or pilot studies. The clinical or laboratory data derived from them will be used as a basis for selecting the most promising materials
which then will be subjected to long term and very costly clinical evaluation studies.

Some important questions that should be answered in these short term screening procedures are:

1. The comparative inhibitory effect of the materials on early supragingival and subgingival calculus formation.
2. The relation of the deposit that develops (or is inhibited) to the periodontal structures, and
3. The probable mechanism of the inhibition, as ascertained from chemical, physical and microbiological evaluation.

The direct (or clinical) calculus quantitating methods that are recommended by Volpe (1974) for short term screening procedures are the Calculus Surface Index of Ennever, Sturzenberger and Radike (absence or presence of supragingival and subgingival calculus) and the Marginal Line Calculus Index of Muhlemann and Villa (relationship of supragingival calculus to the gingival tissues). The Marginal Line Calculus Index can also measure early subgingival calculus formation in the gingival crevice.

The indirect (or clinical-laboratory) calculus quantitating method that is recommended for studies of this type is the Standardized Foil Technique of Marthaler, Schroeder and Muhlemann.
3.4.2.2. Long Term Clinical Trials

Longitudinal experimental studies in human beings are difficult, time consuming and expensive. In studies of this nature, selected materials are carefully evaluated in a duration corresponding to the actual in vivo calculus accumulation pattern. This is a relatively long period of time of up to 1 year or longer. Usually a selected inhibitory material is compared to its proper control formulation in a series of carefully conducted and supervised investigations to establish and document the efficacy of the material.

Since the data acquired from such long term studies will probably be subsequently reviewed by government food and drug agencies, it is important that the calculus quantitating method utilized be very accurate and have acceptable examiner reproducibility. The method should also be uncomplex, since several investigators will be using the same procedure in independent investigations.

Because these studies are conducted over relatively long periods of time, with calculus quantitating examinations being conducted at approximately 3-monthly intervals, the predominant amount of calculus encountered will be supragingival.
Volpe (1974) recommends the Probe Method of Calculus Assessment of Volpe and Manhold for these studies. The calculus quantitating components of the Periodontal Disease Index of Ramfjord and the Oral Hygiene Index Simplified of Greene and Vermillion are also recommended for use in long term studies, especially when investigators are already very experienced in their application.

Volpe (1974) also justifies the use of mandibular anterior teeth only in all the calculus quantitating methods mentioned. A high correlation between the lower anterior teeth region and the full mouth has been established for the CSI, the Probe Method, the PDI and OHI.

The baseline data for most studies is taken following a prophylaxis. Most of the first calculus to form are found in the lower anterior region. However the objective of the study will influence the decision between a partial mouth or a full mouth recording.

In a mouth wash study, sets of teeth can be the index teeth. However, in a tooth brushing study, all teeth should be studied because of uneven brushing methods.
4. INDICES FOR MEASUREMENT OF GINGIVAL INFLAMMATION

4.1 LITERATURE REVIEW OF SELECTED GINGIVAL INDICES.

From a review of literature, there are almost as many indices for the measurement of gingival inflammation as there are investigators who have reported on the subject. The same investigator usually modifies a previously used index in subsequent studies. These observations suggest that no one index is the most suitable or ideal for all purposes.

Some of the guidelines in evaluating an index for gingival inflammation are (Hazen 1974):

1. An index should be simple to use with minimal expenditure of time and cost.
2. Criteria defining the components of the index should be clear and understandable to promote accuracy and reproducibility.
3. A severity index should be equally sensitive throughout and should indicate the clinical stages of the disease process in a meaningful way.
4. The index should be amenable to statistical analysis.

All the indices discussed in this chapter will be evaluated according to these four criteria.
4.1.1 Descriptive Indices

Descriptive indices of gingival inflammation appear early in the literature and have been used in studies as late as the 1960's (Ainsworth & Young 1925; Marshall-Day & Tandan 1944; Pindborg 1951; James, Jackson, Slack & Lawton 1960; Zachrisson 1968).

The results of these studies were usually presented as the percentage of subjects having normal gingiva, slight gingivitis, moderate gingivitis, and severe gingivitis. They do not lend themselves to statistical analysis and thus lack application to present day studies.

4.1.2 Present or Absent Indices

Several investigators have used variations of "present or absent" indices which do not consider the severity of gingival inflammation (King, Franklyn & Allen 1944; Arno, Waerhaug, Lovdal & Schei 1958; Hoover & Lefkowitz 1965; Goose, Goward & Downham 1968; Baume 1968).

Arno et al (1958) examined the buccal, lingual, mesial and distal gingiva of each tooth for inflammatory changes. It was noted whether inflammation was present or absent.
If a large population is being examined for the prevalence of gingivitis, the approach of Baume (1968) can be considered. He reported gingivitis as "the percentage distribution of individuals with one or more signs of gingival inflammation around one or more teeth".

These methods would inevitably result in extremely high prevalence scores and would not be useful for determining the periodontal status of a population or the evaluation of therapy.

Recent researchers have refined the "present or absent" type of indices by selecting to record a single entity which is both sensitive and specific for gingivitis. Gingival bleeding has been favoured by many researchers as such a criteria.

Muhleman & Mazor (1958) recognized bleeding from the sulcus as the earliest sign of gingivitis. Further support was provided by Lennox and Kopczyk (1973) and Meitner et al (Meitner, Zander, Iker & Polson 1979) who noted that bleeding actually preceded clinical inflammation.

The bleeding indices would be simple, reproducible with little examiner training, require little time to conduct an oral examination and lend themselves to statistical analysis. Problems arising from assigning
relative weights to different gingival inflammation parameters of severity scales would also be avoided.

At present there is little evidence that the severity of gingivitis is related to the progression of inflammation to the deeper supporting structures of the teeth with subsequent pocket formation. Hence the approach of just recording whether or not inflammation is present in the gingiva might be a useful alternative in gingivitis studies.

4.1.2.1 Gingival Bleeding Index (Carter & Barnes)

The Gingival Bleeding Index (GBI) of Carter and Barnes (1974) recorded the presence or the absence of gingival inflammation as determined by bleeding from interproximal gingival sulci.

Each interproximal area with a mesial or distal sulcus component was recorded as a unit. Unwaxed dental floss was passed interproximally and carried into the gingival sulcus depth. It was then moved in an incisogingival motion for one double stroke. Care was taken not to lacerate the papilla and a new length of floss was used for each unit. Thirty seconds was allowed for any evidence of bleeding to be recorded.
A weakness of the index is that it cannot be reproduced immediately. Also the thickness and the texture of the floss used were not standardized. The handling of the floss through the interproximal areas was another variable that may affect the reliability of the test. No comparison study has been done in the eliciting of interproximal bleeding using a periodontal probe with the floss method.

4.1.2.2 Gingival Bleeding Index (Ainamo & Bay)

The Gingival Bleeding Index (GBI) proposed by Ainamo and Bay (1975) recorded the presence or absence of gingival bleeding using a blunt probe. Bleeding occurring within ten seconds was recorded as a positive finding. The number of bleeding points was expressed as a percentage of the number of gingival margins examined.

This method has been shown to correlate strongly to the GI scores by Silness and Loe of the same persons. It has been used in both epidemiological studies and short term trials (Ainamo & Holmberg 1974; Bay & Ainamo 1974).

Modification of this method are used in recording gingivitis in the 1977 WHO Oral Health Surveys Basic Methods (WHO 1977) and also in the Community Periodontal Index of Treatment Needs (CPITN) (Ainamo, Barnes, Beagrie,
Ainamo and Bay (1975) reported that at GI = 0.7 bleeding on pressure will not occur at the gingival margin and suggested this as the goal for public health services.

4.1.3 Numerical Indices

4.1.3.1 The PMA Index Modified by Parfitt

The PMA Index and its variations have been widely used since its introduction by Schour and Massler in 1950. (Schour & Massler 1947; 1950; 1952). The index operates on the assumption that inflammatory changes tend to begin in the papillary gingiva spreading into the marginal gingiva and then in time to the attached gingiva. The extent of the gingivitis serves to indicate its severity.

No mandatory examination method or procedure for determining the index has been presented or followed. Although the index has been widely used in epidemiologic studies, questions have been raised as to its validity. Weisinger (1970) stated that the PMA Index does not appear to be effective as an indicator of changes in gingival health. In addition calibration of examiners is difficult (Waerhaug 1966) and comparability between examiners may be difficult to achieve.
Parfitt (1957) modified the PMA Index by adding examination of buccal and lingual gingiva and a severity rating. The index is outlined as follows:

0 = No clinical evidence of inflammation.

P, M, or A = Indicated a detectable hyperemia in the papilla, margin or attached gingiva. This was recognizable by a research worker.

1 + = Denoted there was also a loss of stippling, redness, swelling or bleeding on pressure. Mild gingivitis.

2 + = Denoted that severity was such that the patient might complain of symptoms such as bleeding, sensitivity, itching sensation or tenderness. The patient was usually aware of the condition.

3 + = Denoted the presence of severe hyperemia or obvious swelling or that haemorrhage occurred spontaneously on the slightest touch of food or toothbrush. Severe gingival disease.

The presence of inflammation and its severity in each gingival area was recorded separately. Both buccal and lingual aspects were evaluated and recorded.

A severity index was arrived at as follows:

If D or M was recorded, the score = 1; if A was recorded, there was an additional score of 1. When gingival inflammation was scored (1+, 2+ etc) this was added to the score so that a recording of PMA 3+ would equal 5.
The PMA Index and its variations make no provision for recording of periodontal destruction and hence are acceptable only in the recording of superficial gingivitis.

4.1.3.2 Periodontal Index (PI, Russell)

The Periodontal Index was designed by Russell (1956) as a more comprehensive index to cover both gingivitis and periodontitis. Progressive stages recorded were inflammation of the gingiva, pocket formation with consequent loss of alveolar bone, actual loss of function of the tooth and eventually the tooth itself.

The scores assigned are:

0 = Negative. There is neither overt inflammation in the investing tissues nor loss of function due to destruction of supporting tissue.

1 = Mild gingivitis. There is an overt area of inflammation in the free gingivae which does not circumscribe the tooth.

2 = Gingivitis. Inflammation completely circumscribes the tooth, but there is no apparent break in the epithelial attachment.

6 = Gingivitis with pocket formation. The epithelial attachment has been broken and there is a pocket (not merely a deepened gingival crevice due to swelling in the free gingivae). There is no inter-
ference with normal masticatory function, the
tooth is firm in its socket and has not drifted.

8 = Advanced destruction with loss of masticatory
function. The tooth may be loose, may have drifted,
may sound dull on percussion with a metallic
instrument, may be depressible in its socket.

The average score for the teeth in the mouth of
an individual is the score for that person. Most persons
with a clinical diagnosis of gingivitis score from 0.1
to 1.0, those with frankly established destructive phases
of the disease from 1.5 to 5.0, and those in the terminal
stages of the disease from 4.0 to 8.0, the maximum score.

Reporting is limited to quite obvious lesions and
when an examiner is in doubt, he is instructed to report
the lesser score. A high degree of inter-examiner repro-
ducibility can be achieved with trained examiners, and
at the cost of an under-estimation of the total number
of lesions (WHO 1961).

Ramfjord (1959) criticised the inadequate examin-
ation procedures of the Periodontal Index. There is no
drying of the saliva for evaluation of colour of the
tissues and no palpation for density and bleeding tendency.
There is no routine use of a probe which is only used when
the examiner wishes to verify a pocket. The index does
not differentiate between shallow or fairly deep pockets,
except at the stage when the tooth is about to lose its
function.
WHO/ICS data (WHO 1977) indicated that children aged 8-9 and 13-14 years have a high score of 0.6 (PI). It is not sure if this figure represents the onset of the adult form of the disease or if this is only a transitional inflammation. Croxson (1983) felt that the PI may not be valid in measuring periodontal disease in children under 15 years.

The PI was designed strictly for assessing the overall periodontal disease prevalence in large populations in field conditions. It merely assumes yes or no as to whether the tooth has gingivitis, pocket formation or has lost its function due to periodontal destruction.

The greatest value of the PI is the enormous volume of data generated through its use in diverse population studies of periodontal disease (Russell 1967). Sheiham and Strifler assessed periodontal disease using PI, PDI, radiographic and mobility assessments (1970). Findings indicated that the PI discriminated between population groups as efficiently as the PDI plus radiographic and mobility scores. In the comparison of data between population groups, the effect of under-estimation of the disease by the PI is virtually nullified.

In conclusion, the PI may be applied very swiftly with a minimum of equipment. It is sensitive to differences
between moderate and advanced stages of the disease. It has been used with success to make comparisons between two populations, within segments of a population, and to estimate change in status of a population over short or long spans of time.

4.1.3.3 **Gingival Scores of Periodontal Disease Index**

*(PDI, Ramfjord).*

Ramfjord (1959) initiated the idea of scoring selected teeth as indicators of the periodontal condition of the entire mouth. He used the maxillary right molar, maxillary left central incisor, maxillary left bicuspid, mandibular left first molar, mandibular right central incisor and mandibular right first bicuspid.

The gingival unit was scored as a unit around each tooth as follows:

G0 = Absence of inflammation

G1 = Mild to moderate inflammatory gingival changes not extending all round the tooth.

G2 = Mild to moderate gingivitis extending all round the tooth.

G3 = Severe gingivitis characterised by marked redness, tendency to bleed and ulceration.
The procedures of examination are more detailed than in either the Russell PI or the Parfitt PMA Index. The field should be dried to evaluate gingival colour. Palpation, probing and observation should be combined to evaluate form, density and tendency of the gingiva to bleed.

The gingival scores of the PDI can be combined with pocket depth or loss of attachment measurements to give a composite score which reflects both the gingival and the periodontal condition. The PDI is intended to be used in epidemiological studies as well as clinical studies.

4.1.3.4 Gingival Index (GI, Silness & Loe)

The Gingival Index does not consider periodontal pocket depth, degree or bone loss or any other quantitative change of the periodontium. The criteria are confined only to the qualitative changes in the gingival soft tissue.

Silness and Loe (1964) selected the maxillary right first molar, maxillary right lateral incisor, maxillary mandibular left lateral incisor and mandibular right first bicuspid for assessment of the gingival condition.
0 = Normal gingiva
1 = Mild inflammation - slight change in colour, slight edema. No bleeding on probing.
2 = Moderate inflammation - redness, edema and glazing. Bleeding on probing.
3 = Severe inflammation - marked redness and edema. Ulceration. Tendency to spontaneous bleeding.

Scoring procedures for the GI requires light drying of the teeth and gingivae, mirror and a pocket probe. Each gingival unit (buccal, lingual, mesial and distal) of the individual tooth is scored. Scores from the four areas are added and divided by four to give the Gingival Index of the tooth. Scores for individual teeth could be grouped and divided by the number of teeth examined to give the score for the group of teeth. With chairside assistance and optimum conditions, scoring the full mouth requires two to five minutes (Loe 1967).

The Gingival Index considers only the state of health of the soft tissues. Loe (1967) felt that the PDI composite score was basically wrong in combining the varying quality of the tissues with quantity of the pocket depth measurements. Also there would seem to be no real need for transforming pocket depth measurements in millimeters to a different system of figures in the pocket scores of the PDI.
Alexander et al (Alexander, Leon, Ribbons & Morganstein 1971) compared inter and intra examiner agreement in scoring gingivitis clinically using the GI and the PMA Index. They found the Gingival Index system had the advantage that clear mandatory instructions had been laid down for its use. After extensive examiner training users of both indices achieve a high degree of correlation between the PMA and the GI scores.

Shaw and Murray (1975) found high correlations between the mean GI scores on first and second examinations both within and between examiners.

Downer (1972) tested the PMA Index, GI and PDI for efficiency of score when using the criterion of selected teeth only, as opposed to full mouth examination. He found all the partial mouth scoring systems had high correlations with full mouth scores for gingivitis while that of the GI had the highest correlation.

4.1.3.5 The Suomi and Barbano Index

Suomi and Barbano (1968) and Suomi (1969) examined the gingiva around all teeth in these two studies. Each gingival margin and papilla is scored on a basis of 0-2.

0 = Absence of inflammation. Stippling usually noted.
1 = Inflammation present. A distinct colour change to red or magenta evident. There may be swelling and loss of stippling. The gingiva may be spongy in texture.

2 = Severe inflammation. A distinct colour change to red or magenta. There is swelling, loss of stippling and a spongy texture consistency. There is either gingival bleeding with general probing or inflammation has spread to the gingiva.

It was stated in the later paper that hypertrophy, recession or change in gingival contour in the absence of colour change was not considered to be inflammation.

Each quadrant of the mouth was divided into three segments: molar, premolar and anterior teeth, creating 12 segments.

The mean gingivitis score is obtained by adding the scores of units of the segments and dividing by the number of units examined.

4.1.3.6 Dental Health Centre Index (DHCI, Smith et al)

Smith, Suomi, Greene & Barbano (1970) devised another index in which eight teeth were selected for scoring: all first permanent molars, the upper right central incisor, the upper left first bicuspid, the lower
left central incisor and the lower right first bicuspid.

The facial and lingual gingival tissues were scored separately for inflammation. The criteria for scoring were based only upon colour change and the extent of inflammation around the particular tooth.

0 = No inflammation. Gingiva adjacent to the tooth surface being examined is pale pink in colour and firm in texture. Swelling is not evident and stippling can usually be noted.

1 = Inflammation not encompassing all tissue adjacent to the tooth surface. Gingiva is a definite, red or magenta colour. (including papilla).

2 = Inflammation encompassing all tissue adjacent to the tooth surface (including papilla).

In the study intra-examiner agreement in scoring gingival inflammation was reported to improve from 79.5 percent on the first day to 84 percent on the third day for the Ramfjord method and from 59.3 percent to 86.9 percent over the same period for the DHI.

4.1.3.7 **Gingival Scores of the Gingival-Periodontal Index (GPI - O'Leary)**

O'Leary, Gibson, Shanon, Schwessler & Nabers (1963) divided the mouth into six segments and reported only the
the severest lesion in the segment as the gingival score for that segment.

For uses in clinical trials, this would result in loss of necessary accuracy. However this approach is suitable in screening a large number of subjects for the evaluation of periodontal status and documentation of the need for treatment (O'Leary 1967).

Cohen et al (Cohen, Friedman, Shapiro & Kyle 1969) modified this approach by dropping the segmentation of the mouth, but still evaluating the gingiva around each tooth as a unit.

0 = No overt inflammation, gingival form was consistent with periodontal health.
1 = Slight inflammatory changes, blunting of papillae, loss of firmness but not encircling the tooth.
2 = Slight inflammatory changes that involve both buccal and lingual aspects.
3 = Presence of ulceration, spontaneous bleeding, loss of interdental continuity or marked deviation of contour.
4 = Buccal or lingual recession that exposed the root surface.

The average gingival score equals the total score divided by the number of units scored.
Recession was given the highest score which infers that such a lesion is due to more severe inflammatory changes. However, there is no evidence for this.

4.1.3.8 **Navy Periodontal Disease Index**

(NPDI, Hancock & Wirthlin).

Hancock & Wirthlin (1977) formulated the Navy Periodontal Disease Index after Russell's PI. The first part is the gingival score.

0 = Gingival tissue is normal in colour and firm.
1 = Inflammatory changes present: any change from normal of colour and density, enlargement or blunting of papillae, tendency to bleed upon probing or palpation. The changes do not encircle the tooth.
2 = Inflammatory changes completely circumscribe the tooth.

The second part is the pocket score. Six measurements are recommended with a calibrated periodontal probe. The greatest single measurement determines the pocket score for the tooth.

0 = Probing reveals sulcular depth not over 3 mm.
5 = Probing reveals pocket depth greater than 3 mm but not over 5 mm.
8 = Probing reveals pocket depth greater than 5 mm.
The six teeth selected by Ramfjord (1959) were examined and scored. The score for a tooth is the sum of its gingival and pocket scores. The total NPD1 score is the sum of the scores for the six selected teeth.

Treatment recommendations were also laid down.

0-2 = Oral prophylaxis, plaque control instruction.
5-7 = Complete oral examination, periodontal treatment, plaque control instruction.
8-10 = Complete oral examination, periodontal treatment initiated by general practitioner, with possible referral to periodontist.

The correlation of the gingival scores to the Navy Plaque Index is high at 0.75 (P<0.01). However, the combined gingival and pocket scores of the NDPI only correlate with the Navy Plaque Index at a relatively low level at 0.55 (P<0.01). This indicates pocketing is an irreversible change and its presence is not reflected by the amount of supragingival plaque scored by the Navy Plaque Index.

The NDPI is adequate for screening patients clinically for need of periodontal treatment. Its unrefined gingival scoring portion does not lend itself to the critical evaluation of gingival tissues in clinical trials. In population studies, its routine use of a probe may result in disclosing more advanced lesions than the PI. The reliability of these data will largely depend on the probing skills of the examiners.
4.1.3.9 Sulcular Bleeding Index
(SBI, Muhlemann and Mazor)

Muhlemann and Mazor (1958) in a study on school children, scored only the papillary and marginal areas of the gingivae. Scoring of the attached gingivae was dropped because it was rarely involved. The gingival areas were assessed as follows:

0 = No inflammation;
1 = Bleeding from gingival sulcus on gentle probing. Tissue otherwise appear normal.
2 = Bleeding on probing, plus a change in colour due to inflammation. No swelling or edema.
3 = Bleeding plus a change of colour and edematous swelling.
4 = Ulceration or additional symptoms.
The average SBI = \( \frac{\text{Sum of all scores}}{\text{Number of areas scored}} \)

The first inflammatory symptom defined in this study was "bleeding from gingival sulcus on gentle probing."
This is in contradiction to the GI of Silness and Loe, Parfitt's modified PMA Index and others, which recognize a change in colour of the gingival tissues to precede gingival bleeding on probing.

In a later paper, Muhlemann & Son (1971) subdivided score 4 into: (1) Bleeding on probing and obvious swelling
with or without change in colour; (2) bleeding on probing
and spontaneous bleeding and change in colour, marked
swelling with or without ulceration.

They reported that the SBI scores 1, 2 and 3 closely
correspond to GI scores 0, 1 and 2 respectively. The
higher sensitivity of the SBI was due to inclusion of
the sulcus bleeding criterion.

Schneider, Hampel, Birkholz and Klemm (1967)
reported on the reproducibility of the SBI. Correlation
coefficients for anterior teeth by three investigators
prior to calibration ranged between 0.73 and 0.80.
After calibration they ranged between 0.80 and 0.83.

4.1.3.10 The Gingival Bleeding Time Index
(Nowicki et al)

Nowicki, Vogel, Melcer and Deasy (1981) formulated
a bleeding time index from the occurrence of gingival
bleeding during elapsed time periods after gingival
stimulation.

A Michigan "0" probe was inserted in the sulcus
until slight resistance was felt and the gingiva was
stroked back and forth once over an area of approximately
2 mm. The probe was removed and the time for bleeding
to occur was recorded.
If no bleeding was evident after 15 seconds, the stroking procedure was repeated and bleeding time recorded up to an additional 15 seconds.

0 = No bleeding was evident within 15 seconds after second gingival stimulation.
1 = Bleeding occurred between 6 and 15 seconds after the second stimulation.
2 = Bleeding occurred between 11 and 15 seconds of the first stimulation or within 5 seconds of the second stimulation.
3 = Bleeding within 10 seconds of the initial stimulation.
4 = Spontaneous bleeding prior to stimulation.

A high correlation was found between bleeding time with the GI of Silness and Loe and gingival fluid flow, -0.73 and -0.46 respectively (\( P < 0.001 \)).

Such a method will not be applicable in studies of large populations. Its application in short term clinical trials still remains to be proved.
4.1.4 **Photographic Methods**

Photographic methods of assessing gingival health have been used. Massler, Rosenberg, Carter & Shour (1957) claimed good inter and intra-examiner reproducibility in using colour photographs to assess labial gingival conditions. They stated that good colour photographs were as important to the evaluation of gingival changes as good radiographs were for the evaluation of hard tissue changes.

Jackson (1962) used Kodachrome colour transparencies in a clinical trial to set his standard of clinical examinations initially. The transparencies were reviewed prior to subsequent examinations to ensure these standards were reproducible.

In another study, Suomi, McClendon & Fransden (1972) reported that visible changes in gingival colour could not be determined from the colour slides and that reproducibility was not any better than that in clinical evaluation (about 80 percent). The dissimilar results between the photographic and clinical procedures were suggested to be due to differences in the intensity and angulation of light directed at the gingiva.

All the studies described so far used only anterior labial gingiva. Lees (1974) reported that photographs were unreliable for assessing oral hygiene or gingival
state in the molar region, particularly in young children. Even though measures were taken to standardize film, exposure and developing, variations in colour density on the films were apparent.

Despite all the limitations of photographic methods, a series of good quality and reasonably standardized colour transparencies has advantages in the assessment of examiner variability and may be useful in standardization of examiners (Davies, Kruger & Holman 1967; Llewelyn & Addy 1979).

The colour transparencies taken at the time of the initial clinical examinations in a longitudinal study are permanent records which can be constantly referred to as the baseline condition. The whole series can be reviewed by a large number of examiners simultaneously. Photographs also have the advantage of being assessed blind in a random fashion, thus limiting the possibility of bias.
4.2 PROBLEMS IN SCORING GINGIVAL INDICES

One of the requirements listed by Hazen (1974) of an ideal index was: a severity index should be equally sensitive throughout and should indicate in a meaningful way the clinical stages of the disease process.

The statement implies that we are able to identify the various stages of the inflammation clinically. The visual changes of colour, density and form are all subjective interpretations however. The presence or absence of gingival bleeding, rather than visual inflammation, as an indicator of early gingival pathology is a more objective clinical sign. Unfortunately, strong subjective components exist in a clinical examination for gingival bleeding. The force of periodontal probing and the state of the gingival tissue are two major variables that affect the outcome of the examination.

Furthermore, even if some of the stages are identified and given a figure, there is no evidence that these arbitrary scales represent equal steps along the course of a developing inflammation. Many existing indices thus fall short of the above stated requirements.

The clinical scoring criteria of the gingival indices - visual changes of inflammation and the bleeding tendency of the tissue - have been studied by many researchers
who correlated them to other scientific diagnostic methods for gingival inflammation.

4.2.1 Clinical and Histologic Correlation of Gingivitis

Histologic studies have characterized the pathologic changes in periodontal disease as an increase in inflammatory cells associated with a loss of collagen (Rudin, Overdiek & Rateitschak 1970; Schroeder, Graf-de-Beer & Attstrom 1975; Payne, Page, Ogilvie & Hall 1975), proliferative and degenerative epithelial changes (Zachrisson & Shultz-Handt 1968; Lindhe, Schroeder, Page, Munzel-Pedrazzoli & Hugoson 1974), and apical migration of the junctional epithelium associated with loss of periodontal fibre attachment and supporting alveolar bone (Schroeder & Lindhe 1975; Lindhe, Hamp & Loe 1975).

Studies attempting to define associations between clinical and histologic characteristics of periodontal disease have reported both weak (Ambrose & Detamore 1960; Zachrisson & Shultz-Handt 1968; Stallard, Orban & Hove 1975; Appelgren, Robinson & Kaminski 1979) and strong correlations (Oliver, Holm-Pederson & Loe 1969; Hancock, Cray & O'Leary 1979; Greenstein, Caton & Polson 1981).
Ambrose and Detamore (1960) observed that the exact histologic state of the tissues was impossible to determine clinically. An apparent chronic inflammation on occasion would reveal minimal inflammation on biopsy and vice versa.

Zachrisson and Shultz-Handt (1968) found a correlation between clinical and histologic diagnosis in only about 50 percent of the cases. Stallard et al. (1970) concluded that the alteration in colour, texture and contour was a direct result of inflammation. But the degree of change correlated poorly with the severity of inflammation microscopically. Hara et al. (1975) found a closer relationship between microscopic inflammatory changes and the gingival collagen content in comparison with the Gingival Index scores. Appelgren et al. (1979) established a new histologic classification corresponding to the clinical criteria of the Gingival Index of Silness and Loe. The most clearly identifiable criterion of the GI, the bleeding tendency, did not correlate with its morphologic criteria, the number of functionary vessels in the biopsied specimens.

Conversely, Oliver et al. (1969) reported inflammatory cell densities to correlate well with GI scores. Strong correlations between clinical and histology scores were also found by Hancock et al. (1979). Greenstein et al. (1981) reported that clinical sites with visual inflamma-
tion had a significantly larger percentage of inflamed connective tissue compared with sites without inflammation. Thus visual inflammation at a clinical site may be a reflection of the magnitude and extent of the inflammatory lesion. However, there were no quantitative differences in vasculature related to the presence or absence of bleeding. Greenstein et al (1981) suggested that structural alterations of vessel walls resulting in capillary fragility and permeability predisposed to bleeding upon probing.

In general, increasing GI scores show a tendency to increase with the density and the area of inflammatory cell infiltrate in sections. This substantiates the clinical applicability of GI.

The wide range of correlations reported between GI scores and histology sections may be due to limitations in assessing the degree of inflammation in microscopic specimens. Virtually all investigators have reported the presence of inflammatory cells in clinically normal and inflamed specimens (Bernier 1950; Zachinsky 1954; Rudin et al 1970; Schroeder et al 1973; Greenstein et al 1981). There is always the problem in acquiring biopsy specimens of sufficiently high quality to make the required observations and measurements (Payne et al 1975). Oliver et al (1969) had also found that stains used in microscopic preparations for general morphology often
often did not reveal the various degrees of gingival inflammation in gingival pathohistology studies.

4.2.2 Clinical and Gingival Crevicular Fluid Correlation in Gingival Inflammation.

The gingival crevicular fluid (GCF) is produced through leakage of plasma fluids and proteins due to increased permeability of the vessels of the crevicular plexus (Novaes, Shapiro, Fillios & Wood 1980). The fluid passes through the connective tissue and enters the gingival sulcus through the intercellular spaces of the pocket epithelium. GCF is reported to act as a transport vehicle for salts and immunoglobulins to enter the oral environment (Holmberg & Killander 1971; Shillitoe & Lehner 1972).

The correlation between gingival fluid flow and severity of gingival inflammation has been extensively studied and in most studies a positive correlation was found between gingival fluid flow and clinical inflammation (Brill & Bjorn 1959; Egelberg 1964; Loe & Holm-Pedersen 1965; Oliver et al 1969; Rudin et al 1970; Daneshmand & Wade 1976).

There seems to be a general consensus that the GCF is sufficiently indicative of the gingival inflammatory
state. However, there is controversy whether measurement of the GCF flow is a reliable indicator of inflammation severity. GCF can be recovered from clinically healthy gingiva by a number of researchers (Egelberg 1964; Wilson & McHugh 1971). One report has shown that plaque products such as hyaluronidase can increase GCF flow without a change in the inflammatory state of the gingiva (Awwa 1968). Experimental evaluations of the protein constituents of GCF in attempts to indicate disease activity have not been successful (Schenkein & Genco 1977; Shapiro, Novaes, Fillios, Simons & Goldman 1980). Shapiro et al (1980) explained the phenomenon of a more dilute sulcular exudate in the clinically severe inflammatory state was due to an increased fluid flow compared to the clinically normal patients. Many conflicting results may in part be due to lack of standardized methods and materials for sampling GCF.

Oliver et al (1969) investigated the relation between Gingival Index, the exudate measurements and the microscopic appearance of the same gingiva in humans. It was found that exudate measurements correlated less to microscopic appearance than the GI scores. In a similar study Hancock et al (1979) obtained high correlations for GI scores and histology of the tissue ($\gamma = +0.89$, $P < 0.001$). The correlation between GI scores and GCF flow was significant at the 1 percent level but was of a low degree. ($\gamma = +0.38$, $P < 0.01$). Daneshmand & Wade (1976)
also reported a low positive correlation between histologic indices and GCF measurements. But a stronger correlation was found between the GCF flow rate and the GI scores.

From all the studies described above, it can be concluded that any of the three parameters - visual changes of inflammation, GCF flow and microscopic appearance only partially reflects the morphology of gingival inflammation. This is not at all surprising in view of the fact that the inflammatory process is a dynamic process involving a series of ultrastructural changes and chemical events in addition to those seen clinically or in fixed and stained microscopic specimens.

The GCF flow and biopsy methods involve laboratory techniques more suited to researchers and have limited applications in studies of a large number of subjects or in daily dental practice. Despite the subjectivity of scoring visual changes of inflammation, the gingival indices are simple and practicable for most purposes. The strong correlations of the gingival indices to both histologic and GCF measurements seem to warrant their continual use in evaluating gingival inflammation.
4.2.3 Problems with Gingival Bleeding Indices

4.2.3.1 Bleeding as a Diagnostic Criterion

The need for objective signs in the assessment of periodontal changes has been frequently emphasized (Ramfjord 1959; Davies et al. 1967; Alexander 1970; Hazen 1974). Bleeding is either present or absent whereas colour and other visual changes relating to the degree of inflammation are only subjective estimations by the examiner.

The use of bleeding instead of visual inflammation as an indicator of early gingival pathology has been supported by Muhlemann & Son (1971), Lennox & Kopczyk (1973) Carter & Barnes (1974) and Ainamo & Bay (1975). Meitner et al. (1979) reported that a greater number of early gingival lesions manifested bleeding alone compared to either visual inflammation alone or a combination of visual inflammation and bleeding. Hence bleeding after probing might be a more sensitive indicator of gingivitis.

Bleeding on probing is also used for the detection of an inflammatory lesion which may persist at the base of a pocket (Garnick 1980) in the absence of visual inflammation at the gingival margin. Persistence of bleeding on probing from pockets in the absence of marginal inflammation is one of the criteria of progressive
chronic periodontitis (Seymour et al 1979). A higher correlation between gingival bleeding and percentage of spirochetes present in subgingival plaque has been reported (Slots, Mashimo, Levine & Genco 1979).

Bleeding on probing thus has the advantage of relative objectivity in detection of early gingivitis and also submerged periodontal lesions at the apices of pockets.

4.2.3.2 Reliability of Bleeding Indices

The reliability of gingival bleeding indices is affected by a strong subjective component in a clinical examination of gingival bleeding.

The tip of a periodontal probe is inserted into and moved along within the gingival sulcus by the examiner. Although the term "gentle" is always used in describing the technique there is no control of the forces applied. It has been shown that there is a great variation in probing forces even among experienced clinicians (Gabathuler & Hassell 1971). Hassell, Germann & Saxer (1973) reported forces during sulcus probing varied from 23.3 to 109.2 ponds (one pond = one gram absolute force). Robinson & Vitek (1979) regarded 25 ponds as the most common load applied.
Freed, Gapper & Kalkwarf (1983) investigated the range of probing forces used by 58 dental practitioners with a pressure sensitive probe and found it to be between 5.0 to 135.0 grams.

Van der Velden and co-workers (Van der Velden & de Vries 1978; Van der Velden 1979; 1980) have repeatedly shown that an increase in probing force results in increases in probe penetration and bleeding tendencies. Caton et al (Caton, Proye & Polson 1982; Proye, Caton & Polson 1982) corroborated the results of Van der Velden. They found that probing depths and percentage of bleeding pockets were always greater when using manual uncontrolled force than those found at even 15 and 50 grams of probing force. In comparing 15 grams with 50 grams of probing force, the difference in percentage of bleeding pockets was as much as 32 percent. Without controlled insertion pressures and clear delineation of probing technique the accuracy of bleeding indices must be questioned.

The above studies cited infer the use of excessive force during probing may elicit a false-positive bleeding tendency in healthy tissues. There is speculation that inaccuracies may be even more pronounced in regions of long epithelial attachments (Listgarten 1980; Van der Velden 1980). The Periodontal Pocket Bleeding Index (Van der Velden 1979) yielded a much higher score than indices which include evaluation of colour and swelling,
eg. the GI of Silness & Loe, and SBI of Muhlemann & Mazor, in post treatment evaluation when swelling and redness had nearly disappeared (Van der Velden 1980). The high bleeding tendency may be due to the fact that the majority of deep pockets are still inflamed after initial treatment. Yet it can also be argued that in deep pockets, the chances of wounding the pocket wall is higher because the probe traverses a longer distance over the pocket wall than in shallow pockets.
4.3 CRITERIA FOR SELECTING A GINGIVAL INDEX

There are many numerical indices for scoring the severity of gingival inflammation. Most of these are weighted, emphasizing for example, colour change (Suomi & Barbano 1968), bleeding (Muhlemann & Mazor 1958; Ainamo & Bay 1975), the facial rather than the lingual or the most severely affected area in a segment (O'Leary 1967). Values for like or similar criteria, e.g. changes in form or colour, are given different weights in different indices. The objectivity of one of these - bleeding on gentle probing - can be improved by standardization of the shape of the probe, the pressure applied and points of application in the gingival crevice or pocket (FDI 1976).

It is unlikely that any gingivitis index is sensitive to all types of gingivitis, has specific meaning for all stages of the disease process, is equally applicable for the needs of all types of studies, provides comparable inter-study data, and is equally useful for severity assessments in all population types.

Hazen (1974) listed four different areas of applications of gingival indices:

1. Periodontal treatment need evaluations.
2. Epidemiologic surveys on prevalence and incidence.
3. Longitudinal experimental studies to evaluate prophylactic
and/or therapeutic measures in population groups.

4. Clinical trials in small, well controlled experimental groups.

The selection of gingival indices for the particular study will be discussed accordingly.

4.3.1 Gingival Indices for Periodontal Treatment

Need Evaluations

These types of indices are used for the assessment of periodontal treatment requirements of large populations when prevalence and not severity is the primary concern (Baume 1968). Some of them are also used in daily dental practice for the recording of gingivitis (Ainamo 1975).

As prevalence is the primary concern, the presence or absence of gingival bleeding is the most usual criterion for scoring gingivitis in this category.

The Gingival Bleeding Index of Ainamo & Bay (1975) records the presence or absence of gingival bleeding on gentle probing with a blunt probe.

The WHO 1977 Oral Health Surveys (WHO 1977) only score "intense gingivitis" on the criteria of marked visual
changes in the gingival colour, form and density, gingival bleeding on digital palpation.

In an effort to reduce examiners' decisions and standardize the procedure in eliciting gingival bleeding, the Community Periodontal Index for Treatment Needs was developed by WHO and FDI jointly (Ainamo, Barnes, Beagrie, Cutress, Martin & Sardo-Infrri 1982). It recommends the use of a special probe to check for gingival bleeding which is the only criterion in scoring for gingivitis. No visual changes are recorded. The objectivity of the gingival bleeding criterion is enhanced by standardizing the equipment and probing forces. It is a simple, quick and reliable method in screening large populations.

All indices for periodontal treatment needs will be further reviewed in Chapter 6 of this treatise.

4.3.2 Gingival Indices for Epidemiologic Surveys on both Prevalence and Severity.

Epidemiologic surveys on the prevalence and severity of gingivitis in large populations require an index which is fairly quick to apply and which needs little equipment and technical facilities.
In surveys of this type, there is usually no need for refined assessments of localization by tooth or area of the mouth, or of the severity of the gingivitis. As it is generally accepted that gingivitis precedes destructive periodontitis, indices which consider both gingival inflammation and periodontal breakdown are preferable.

WHO (1979) recommended the Periodontal Index (PI) developed by Russell (1956) when it is desirable to obtain more detailed epidemiologic information than is possible by using the system prescribed in the basic manual (WHO 1977). To a certain extent, the Periodontal Disease Index (PDI) as proposed by Ramfjord (1959) also fulfills the requirements.

Although the PDI has two scores for gingivitis (Score 1 and 2), it does not really consider the different qualities of gingival inflammation. It merely refers to the horizontal extension of the marginal inflammation around the tooth.

When the study population is young, a high proportion of the scores of PI will be confined to the lower end of the scale, which relates only to gingivitis. It was stated by Warhaug (1974) that the PI was insensitive to the early stages of gingivitis. Thus the PI may not be reliable for measuring periodontal disease for children and young adults. The gingival component of the PDI may be more suitable for scoring young populations.
4.3.3 Gingival Indices for Longitudinal Experimental Studies in Population Groups

Long term studies designed to evaluate the effect of prophylactic or therapeutic measures, or merely to study the development of gingivitis and subsequent periodontal destruction, represent another form of epidemiologic research.

In some cases the same requirements may be satisfactory for this type of study as for the surveys. However, some indications of localization of gingival inflammation in different areas of the mouth, or even at different surfaces of the teeth separately are desirable. For example, in evaluating intensified interdental cleaning, the effect of the method on interdental gingival conditions or even that on the vestibular and lingual aspects of the interproximal areas should be studied separately.

Furthermore, an index with a proper severity scale is needed in the study of the degree of inflammation in the gingiva relating to periodontal breakdown. It is of paramount interest to know whether a gingivitis which bleeds upon gentle probing leads more readily or rapidly to pocket formation and loss of attachment than one which does not bleed.

For these purposes, the Gingival Index (GI) by Silness & Loe (1967) is obviously the index of choice.
Combined with measurements of loss of attachment as described by Glavind and Loe (1967) detailed information may be obtained at corresponding tooth surfaces.

The PI and PDI may also be suitable for some long term studies on gingivitis and periodontal disease. The possibility of using periodic standardized colour photographs should not be disregarded.

The PMA Index (Shour & Massler 1947) as modified by Parfitt (1957) is a more complicated system which may produce valuable information in a longitudinal study. However, the problem of calibration of examiners is considerably greater with this index. Its correlations to other periodontal indices were also found to be low (Ship, Cohen & Laster 1967).

4.3.4 Gingival Indices for Controlled Clinical Trials in Small Groups

A detailed account on the design, conduct and evaluations of clinical trials of agents and procedures for the prevention and treatment of periodontal diseases has been delineated in the 1976 FDI report (FDI 1976).

The small scale controlled clinical trial is usually performed in well equipped dental clinics on a
relatively small group of test persons. Efforts are made to control all known variables, except for the one to be tested.

This type of study is often used in the early stages of human experiments on drugs and other means of prevention or therapy for gingivitis. The choice of an index may depend on the relation of the accretions to gingival health and on the measurement of inhibitory or cleansing effectiveness of an agent or procedure. The amount and location of accretions anticipated, especially when saturation of an index is likely to occur, is also of importance. Because of the small number of observations, very accurate assessments are necessary. However, an overly refined scale may be artificial and of little use in the detection of differences between control and test groups.

The gingival indices which are based on visual changes of colour and form (Shour & Massler 1947; Parfitt 1957; Suomi & Barbano 1968) are too subjective to be used for this type of experiments. The alternative use of a gingival bleeding index with a dichotomous scale (Carter & Barnes 1974; Ainamo & Bay 1975) is too crude for a similar purpose and results in a reduction of sensitivity. The gingival bleeding indices with a proper severity scale (Muhlemann & Son 1971; Nowicki et al 1981) are also subjected to error from non-standardized
periodontal probing forces of various examiners. It was found that the bleeding tendency of the gingiva was not reflected in the vasculature of the histologic sections of the same specimens (Appelgren et al 1979; Greenstein et al 1981) whereas changes in colour and form are in the cell densities of the biopsied specimens (Oliver et al 1969; Hancock et al 1979; Greenstein et al 1981).

The GI takes into account both visual changes and bleeding tendencies. Overall, it has been shown to correlate fairly well with the histologic picture of gingivitis in its very early stage. This allows investigators to let test groups develop gingivitis up to a well defined clinical level, and then reverse it (Hazen 1974).

The GI with its combined criteria of visual changes of form and colour plus bleeding tendency, is the most sensitive of all the gingival indices (Hazen 1974). It is also recommended by WHO (1979) to be used for most clinical trials.
5. INDICES FOR LOSS OR GAIN OF PERIODONTAL ATTACHMENT

The extension of inflammation from the marginal gingiva into the supporting periodontal tissues mark the transition from gingivitis to periodontitis. When periodontitis is present, there may either be a fibrous enlargement of the gingival tissues resulting in a hyperplastic gingivitis, or progressive destruction of periodontal tissues producing periodontal pocketing, recession, or both. Conversely, the gingiva may assume a more normal appearance. In advanced periodontal lesions, the inflammatory front is situated in the depth of the pocket and hidden from view (Holborow et al 1983).

The status of the periodontium, relative to "normality" and various changes due to periodontal disease, is assessed by the condition of the gingiva and alveolar bone, crevicular depth, level of attachment and to a limited extent by tooth mobility (F.D.I. 1976).

The major diagnostic methods outlined by Ramfjord (1967, 1974) in assessment of periodontal support are periodontal probing and roentgenography. Histiometric measurements from histologic block sections of teeth and surrounding tissues can be made with a high degree of precision (Costich & Ramfjord 1968), but the measurements are only limited to a specific time and seldom practicable in the main study of clinical trials.
Excised soft tissue biopsies may also be useful for studies concerned with gingivitis, but provide very little information on loss or gain of periodontal support. Mobility of teeth is important in prognosis in clinical periodontics. However, its place in clinical trials as a diagnostic criterion is less important than probing and roentgenography (Chilton 1974). Many teeth with severe periodontal disease may not be mobile at all (Sheiha 1974).
5.1 PERIODONTAL PROBING

5.1.1 Method & Procedure.

Clinical probe measurements of attachment levels can be made quite accurately with acceptable reproducibility (Glavind & Loe 1967) and are the most meaningful data related to loss or gain of the periodontium.

The level of attachment should be measured from a reasonably fixed point such as the cemento-enamel junction or margin of a restoration to the free gingival margin. The pocket or crevice depth is measured from the free gingival margin to the bottom of the probable crevice. Valuable information may be lost if both measurements are not taken since a deepened gingival sulcus may result from gingival enlargement and/or loss of attachment, and on the other hand pocket depth may be reduced by gingival recession.

The probes should be calibrated on a millimetre scale, be of equal length and thickness, have similarly shaped points and be capable of being held in the same positions by the observer. All measurements have to be made under the same clinical conditions and probing pressure (F.D.I. 1976).

Ramfjord (1974) employed a technique which emphasized a light grasp, light force and a slight angle formed between the working end of the probe and the long axis of
the tooth as the probe entered the gingival crevice. Occasionally it is also necessary to remove heavy deposits of calculus to expose the cemento-enamel junction and access to the gingival crevice before probing.

Hassell et al (1973) and Hurt (1977) emphasized slow deliberate searching rather than the application of force. Pocket topography is more important than absolute pocket depth. Merely inserting the probe once into the pocket is not adequate for objective evaluation of the periodontal condition.

The above is true when probing for treatment purposes. However, in clinical trials, probing is often restricted to certain selected points along the gingival crevice for the sake of reproducibility. These measurements may be repeated over a number of years in some clinical trials (Suomi 1974).

All measurements are rounded to the nearest millimeter, except that anything close to \( \frac{1}{2} \) mm is always reported as the lowest whole number. By assigning all doubtful measurements to the lower score, reproducibility is greater than if a more accurate determination of \( \frac{1}{2} \) mm were attempted (Ramfjord 1974).

A reproducibility test should be repeated prior to institution of a study until satisfactory results are
achieved (Smith & Ash 1964; Clavind & Loe 1967; Ramfjord 1967; Smith et al 1970). Such tests should be repeated during and at the end of the study. In clinical trials the accuracy of scoring is crucial for evaluation of the results which usually involve small variations in periodontal attachment levels with time.

5.1.2 Problems Related to Periodontal Pocket Depth Measurements.

Periodontal probing is one of the primary methods of determining loss of attachment and inflammation of gingival tissues (Loe 1979). The consistency and accuracy of the periodontal probe measurements are particularly critical in evaluating the results of periodontal treatment and of therapeutic agents in clinical trials.

For many years it was assumed that periodontal probing measurements correspond to the actual depth of the sulcus or the pocket as it appeared in histologic tissue sections. This has now been repudiated by recent histology studies by Schroeder & Listgarten (1971), Armitage et al (1977) and Polson et al (1980).

It is now generally agreed that periodontal probing is an imprecise technique and the pocket depth measurement is influenced by many variables. These include probing techniques, the health status of the periodontal tissues,
quality and precision of probe tips, local anatomical factors, length of the junctional epithelium, subgingival calculus and overcontoured restorations (Loe 1979; Listgarten 1980, Sanderink, Mormann & Barbakow 1983).

5.1.2.1 Influence of Periodontal Probing Force on Pocket Depth Measurements.

Pressure is one of the most important variables in measuring pocket depth. A wide range of interexaminer probing forces has been reported by many investigators. Gabathuler and Hassell (1971) in a study of eight experienced clinicians using a probe fitted with a piezoelectric sensor, recorded a range of 3.0 to 54.0 ponds in an anterior segment (1 pond equals approximately 1 gram). Freed et al (1983) using a pressure sensitive probe, investigated the range of probing forces by fifty-eight practitioners and found it to be between 5.0 and 135.0 g.

In addition to a large range of interexaminer probing force, a relatively broad intra-examiner range with a mean of 43.9 was also recorded by Gabathuler & Hassell (1971).

Intra-examiner variations in probing forces may be influenced by access to the area probed. Clinicians often search with greater force in the interproximal areas due to the propensity of this area for periodontal disease.
Anterior teeth which are more accessible were consistently probed with less force than posterior teeth. Moreover, distal units in the posterior segments were probed with the greatest amount of force while facial units of anterior were probed with the lightest (Freed et al 1983). Also the distal measurements on posterior teeth tend to be more variable (Goodson, Tanner, Haffajee, Sornberger & Socransky 1982). In conclusion, impaired vision, the necessity to retract tissues and compromised instrument position may reduce tactile senses in the posterior segments of the dentition. Underestimation of pocket depth could result from inadequate positioning of the probe, particularly with respect to angulation (Ziegler & Allen 1978). Overestimation could result from excessive force used.

Hassell et al (1973) noted only a loose correlation between the depth recorded by the probe and the force applied to it. However, Van der Velden and de Vries (1978) recorded significant differences in the depth recordings with a range of probing forces between 0.15 to 0.75 Newton (0.0098 Newton equals one pond). Similarly Proye et al (1982) found a consistent increase in probing depth and bleeding tendency as probing force increased.

Van der Velden and de Vries (1978) called for a standardization of probing forces in measuring pocket depth and bleeding tendencies. They recommended a probing force
of 0.75 Newton as optimal with probes of 0.63 mm diameter (1979). This is equivalent to a force of 75 ponds. Other investigators (Armitage, Svanberg & Loe 1977; Robinson & Vitek 1979; Garnick, Spray, Vernino & Klawitter 1980) regarded a force between 10 and 25 ponds to be in the mid-range of "gentle" probing forces as determined by experienced clinicians.

Current opinion is that loss of periodontal attachment is best determined using light probing pressure of approximately 8 to 12 g., which does not produce blanching of the tissues (Holborow et al 1983). It is considered that searching for the deepest pockets is more important in diagnosis than refining the amount of pressure applied to the probe (Vittek, Rappaport, Gorden, Munnangi & Southern 1979).

5.1.2.2 Influence of Periodontal Health on Pocket Depth Measurements

The possibility that tissue penetration by the probe could result in overestimation of the anatomic sulcus depth was first suggested by Schroeder & Listgarten (1971). In a later paper Listgarten (1972) listed the degree of inflammatory cell infiltration and accompanying loss of collagen fibres as one of the factors related to the degree of tissue penetration.
Saglie, Johansen & Fløtra (1975) documented a zone of partially destroyed connective tissue fibre existing between the most apical remnants of the junctional epithelium and the most coronal extension of intact connective tissue fibre retained on the root surface of periodontally involved teeth. The zone was reported to have a mean width of 0.43 mm. In the presence of an "advanced" periodontal lesion, this region is characterized by an extension of the inflammatory infiltrate as well as a loss of collagen fibres (Page & Schroeder 1976).

Such a zone offers little resistance to penetration by the periodontal probe. Sivertson & Burgett (1976), Listgarten et al (1976), Armitage et al (1977), Spray et al (1978), Powell & Garnick (1978) and Van der Velden (1979) are all in agreement that the probe tips in inflamed tissue stop at the level of intact connective tissues, that is approximately 0.25-0.4 mm apical to the termination of the junctional epithelium. At standardized probing forces of 20, 25 and 30 pounds, Robinson & Vitek (1979) reported a straight line correlation between GI scores and tissue penetration by the probe.

These findings have clinical significance in the interpretation of probe depth measurements during the initial examination of a patient with periodontal disease and the subsequent evaluations of the effect of various
modes of therapy. In untreated periodontal lesions the overestimation of pocket depth will likely to be within 1-2 mm (Listgarten 1980). The discrepancy is least with minimal inflammatory changes and increases with increasing degree of inflammation. In treated cases, the probe tip stops coronal to the base of the junctional epithelium thus underestimating the sulcus depth (Fowler, Garrett, Crigger & Egelberg 1982).

Success or failure of periodontal treatment as determined by clinical measurements relies particularly on the increase or decrease in probing attachment levels recorded by periodontal probing (Ramfjord, Knowles, Nissle Burgett & Shick 1975; Rosling, Nyman, Lindhe & Jern 1976). Human and animal studies have not provided histological evidence of new connective tissue attachment following conventional periodontal treatment (Caton & Zander 1979; Listgarten & Rosenberg 1979; Caton & Nyman 1980; Steiner, Crigger & Egelberg 1981). It appears that improved probing attachment levels following therapy may not be due to new connective tissue attachment but to improved epithelial adhesion and improved connective tissue tonus preventing the probe from penetrating to pre-treatment levels (Fowler et al 1982).

The length of the junctional epithelium formed following therapy of human periodontal lesions may range from 1.0 to 4.5 mm (Listgarten & Rosenberg 1979). In the absence of inflammation, this epithelium may not be
penetrable during ordinary probing. However if inflammation occurs at the long junctional epithelium, a much wider variation of probe depth measurements would be recorded. A sudden increase of up to 4 mm in clinical probing depth may manifest as the probe traverses the epithelium and/or the adjacent inflammatory infiltrate (Listgarten 1980).

Thus the accuracy of pocket depth measurements can be improved by the establishment of a suitable oral hygiene regime and control of gingival inflammation both prior to and following the surgical elimination of periodontal pockets.

5.1.2.3 Influence of the Periodontal Probe on Pocket Depth Measurements.

Periodontal attachments have been estimated by different investigators using probes of various design (Ramfjord 1959; Glavind & Loe 1967; Ramfjord et al 1973; Sivertson & Burgett 1976; Listgarten et al 1976; Loe et al 1978; Spray et al 1978; Morrison, Lang & Ramfjord 1979; Ainamo et al 1982; Fowler et al 1982).

Probe designs vary in material, size, weight, the angulation between the calibrated tip and the shank of the instrument, the cross-sectional shape and thickness of the blade and calibration (Tibbetts 1969; Van der Velden 1978).
Loe (1979) listed the desirable properties of an ideal periodontal probe:

1. The measurement device must be easily manipulated in the oral cavity with minimal discomfort and minimal trauma to the tissues.
2. It must allow probing forces to be controlled.
3. It must be sterilizable.
4. The probe terminal diameter is to be 0.35 mm; the thickness of the blade 0.8 mm.
5. The sensitivity of the probe is 0.1 mm for linear measurement and the range is from 0 to 15 mm.
6. The calibration of the probe must be accurate and clear to allow easy reading of the mm marking.

(A) **Commercial Probes**

Numerous types of periodontal probes are commercially available. Their cross-sectional shapes vary from round (e.g. the University of Michigan probe, the Williams probe, the Merritt probe and the Gilmore probe) to rectangular (e.g. the Goldman-Fox, the Drellich and the Nabers probes). Slight variation in individual thickness of the same make of probe may affect the results of probing depth when fairly normal and dense gingival tissues are scored (Ramfjord 1959).

Schmid (1967) reported that flexible plastic periodontal probe tips were better in adapting to periodontal
pocket morphology than metal probes. However Sanderink et al (1983) found they had no marked advantages in measuring pocket depth over the metal probe. There were no features of shape retention exhibited but inter-examiner variability was greater with the plastic probe.

(B) Specially Designed Probes

Some authors (Gabathuler & Hassell 1971; Hassell et al 1973; Van der Velden & de Vries 1978; Robinson & Vitek 1979; Freed et al 1983) made special pressure sensitive probes in investigating the relationship between probing forces and tissue penetration by the probe.

Others have made special probes or modified existing probes to obtain readings to 0.5 mm (Lang & Loe 1972; Dragoo & Sullivan 1973; Nelson, Funakoshi & O'Leary 1977). Detsch (1980) recently developed a periodontal probe which utilizes a vernier gauge to permit direct measurement to one-tenth millimeter.

(C) Calibration of Periodontal Probes

Two factors which directly influence the precision of periodontal probes are the accuracy and the mode of calibration. Glavind & Loe (1967) measured all surfaces of 1530 teeth and showed that the method error was less than ± 0.5 mm. Since this small error was not clinically significant, the millimeter was considered to be an appropriate unit of measurement for recording pocket depths
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and loss of epithelial attachments.

The most common calibration of periodontal probes is as follows: the probe is marked in 1 mm increments up to 10 mm; but the 4- and 6-mm marks are omitted to facilitate reading the measurements (e.g. the Merritt, Williams, Goldman-Fox and Nabers probes). The University of Michigan #1 probe has a full range of mm increment markings.

In epidemiological studies, probes with selected millimeter marks are often used. Ramfjord (1959) and Sheiham & Striffler (1970), for instance, used the University of Michigan #0 probe, with only 3-, 6- and 8-mm points indicated. Such a probe was found to be useful in the W.H.O. 1977 Oral Health Surveys in which one of the criteria of advanced periodontal involvement was the presence of a pocket greater than 3 mm. Ramfjord (1959) reported that reproducibility is better and eye strain less following proper training with this probe than with probes that have marks for every millimeter.

Van der Velden (1978) reported that only 60 percent of 4 and 6-mm pockets were read correctly in vitro when using a probe which omitted the two marks when compared to 90 percent of all other measurements. He advocated the use of a probe with marks for every millimeter for clinical studies.
The 621 periodontal probe (Emslie 1980; Ainamo et al 1982) was designed for screening periodontal treatment needs of populations. It has a ball pointed tip of 0.5 mm diameter and a coloured band starting at 3.5 mm and ending at 5.5 mm. This allows easy differentiation of pockets between 4 and 5 mm deep from pockets 6 mm or more.

Winter (1979) assessed the accuracy of calibration of 121 Williams and Goldman-Fox probes and 8 Michigan probes. He found that most markings measured on the probes are not precise. The new Williams and Michigan probes were the most accurate; whereas the older Williams probe by Hu Friedy had the widest range of measurements. They also had the least consistency at each interval.

Variations in the length of commercial probes have been noted by other researchers (Vincent, Machen & Levin 1976; Nelson et al 1977). Detsch (1980) found a commonly used periodontal probe varied as much as 0.3 mm for the first millimeter increment. The variation was thought to be due to the lack of precision in polishing the tips of the probe during manufacture. Wear of the tips did not appear to be significant (Winter 1979). Indistinct millimeter marks on some new Merritt probes were also reported by Van der Velden (1978).

From the above studies, the possibility that an assortment of periodontal probes with inaccurate as well as inconsistent markings accumulating at any private
practice or clinic is quite likely. A researcher should make efforts to standardize the lengths and millimeter increments of the available stock of periodontal probes so as to avoid producing misleading information from using a random selection of inaccurate probes.

5.1.3 **Criteria for Selecting an Index Measuring Loss or Gain of Periodontal Attachment.**

Russell's Periodontal Index (PI) (1956) is recommended by W.H.O. (1979) in epidemiological periodontal disease studies when more detailed information is required than those which can be obtained from the basic manual (W.H.O. 1977).

The PI fundamentally records three crucial stages in periodontal disease: gingivitis (scores 1 and 2), pocket formation (score 6) and the total breakdown of the periodontium (score 8). Probing is only performed to verify the presence of pockets and there is no provision for measuring the depth of any existing pocket. It simply answers yes or no to whether the tooth has gingivitis, pocket formation or has lost its function due to periodontal destruction.

Its simplicity and reproducibility are the strength of the PI in assessing the overall periodontal disease prevalence in large populations. It obviously lacks the
precision for analysing the effects of preventive and therapeutic measures in clinical trials.

Ramfjord's Periodontal Disease Index (PDI) (1959) is also a composite system which records both the gingival and periodontal situation. Here the scores for periodontal destruction are based on loss of attachment as measured in millimeters from the cemento-enamel junction to the bottom of the pocket.

If the loss of attachment measures less than 3 mm, the tooth is given an index score of 4, between 3 and 6 mm, the score is 5 and loss of attachment of over 6 mm scores 6. If the gingival crevice in none of the measured areas extended apically to the cemento-enamel junction the recorded gingivitis score is the PDI for that tooth. The gingivitis score is disregarded for any tooth scoring 4 or over.

The PDI offers more information than the PI in the quantification of periodontal destruction. However, all attachment losses of up to 3 mm are recorded in a single score. This is too gross a method for clinical research (Suomi 1974).

None of the present periodontal indices will provide data with adequate details for clinical trials involving loss or gain of periodontium. For the specific evaluation
of attachment levels, direct measurements reported in millimeters from the cemento-enamel junction are recommended over various other methods (Glavind & Loe 1967; Ramfjord 1974; F.D.I. 1976).

5.2 RADIOGRAPHIC EVALUATION OF PERIODONTAL SUPPORT

5.2.1 Advantages and Limitations of Radiographs

Radiographic examination is indispensable for diagnosis and treatment planning in clinical periodontology. Alveolar bone resorption, the most ominous sequelae of periodontal disease, is difficult to evaluate without the use of radiographs (Marshall-Day & Shourie 1949; Dunning & Leach 1960; Schroeder & Muhlemann 1964).

Many other conditions of interest may be revealed with radiographs, e.g. overhanging margins of restorations, calculus, root anatomy, width and profile of the interdental septa, alveolar bone texture and the continuity and density of the lamina dura.

Radiographs constitute permanent records which may be evaluated blind by any examiner at any time (Russell 1960; Bjorn 1968). In comparison examinations of long term clinical periodontitis studies, radiographs are preferred to clinical probing measurements (Emslie 1974).
Ramfjord (1974) stated radiographs should be used if the principal interest is comparison of bone levels. The rate of progress of the disease can be inferred by observing at intervals the differences in the height of the bone relative to the length of the root in a mesial distal plane through the interproximal space (Goldhaber 1979).

Roentgenographic examination determines alveolar bone height fairly accurately, the error ranging from 0.42 to 1.6 mm (Regan & Mitchell 1963). However radiographic data must be evaluated with discretion, bearing in mind the limitations and potential sources of error.

1. Radiographs do not show bony lesions on the buccal, labial and lingual aspects of the tooth. Buccally and lingually radiographs are unreliable in estimating bone levels (Ramfjord 1974). Underestimation of interproximal bone craters may also occur due to overshadowing by facial and lingual bone margins (Frohlick 1956; Theilade 1960).

2. Radiographs fail to demonstrate the early lesion, underestimate the advanced lesion and are unreliable in recording the morphology of bone deformities (Lang & Hill 1977). Bender & Seltzer (1961) reported that extensive travascular bone could be removed in experimental bone lesions without obvious radiographic change unless the cortical bone was disturbed.
3. Due to the complicated shape of the roots, the amount of root area invested in bone cannot be estimated from radiographs (Brown 1950). The loss of one third of the bone height may involve almost two thirds of the total support (Goldman, Schluger & Fox 1956).

4. Radiographs are especially inadequate in clinical trials where epithelial and connective tissue attachment apparently may be gained without concomitant gain in bone level (Ramfjord 1974). Radiographs do not show the periodontal pocket. They do not distinguish the successfully treated and untreated case. Clinical probing is the method of choice for clinical studies concerning loss or gain of periodontal support (Greene 1968; Ramfjord 1974).

5. The anterior region, although convenient for clinical measurements presents additional problems for radiographic examination relating to the proclination of the teeth, the angulation of the palate and the convexity of the arches (Emslie 1974).

In conclusion, interpretational errors plus discrepancies in angulation and film exposure techniques may all detract from radiographs their diagnostic accuracy in assessment of bone levels.
5.2.2 Standardization of Radiographs in Periodontal Studies

Ensuring comparability between serial radiographs is essential for accurately diagnosing bone level changes in long term clinical studies (Plotnick, Beresin & Simkins 1971; Kelly, Cain, Knowles, Nissle, Burgett, Shick & Ramfjord 1975).

It is important to reproduce accurately the projection geometry and optical density of the exposure. Duckworth et al (Duckworth, Judy, Goodson & Socransky 1983) listed the following desirable criteria for standardizing intra-oral radiographs:

1. The projection used should minimize distortion of the anatomic structures of interest.
2. The ionizing radiation exposure should be the minimum required to provide diagnostic information.
3. The method should be applicable to all sites in the mouth.
4. It should not be uncomfortable to the patient.
5. It should not require extensive training to use.
6. It should use readily available materials.
7. It should provide information about the degree of standardization achieved.

Various techniques of standardizing both the optical densities (Richards 1953; Omnell 1957; Plotnick et al 1970;
Duinkerke, Van der Poel, Van der Linden, Doesburg & Lemmens 1977) and geometric projections (Dawkins 1958; Dalitz 1964; Renggli, Steiner & Curilovic 1971) of radiographs have been devised.

A common method for densitometric standardization is to include in a film-holding device an aluminium wedge which produces a useful range of densities as a basis for comparison. This would increase the sensitivity of the radiographic assay for periodontal disease activity allowing a comparison of the bone mineral content of the alveolus (Duckworth et al 1983).

Geometric standardization requires the use of some type of beam-guiding device to facilitate the alignment of source, object and film. A method proven useful in dental applications employs occlusal registrations as a means of repositioning the film. Devices which have been used are of two types, those mechanically coupled to the source (Rosling, Hollender, Nyman & Olson 1975) and those uncoupled from the source (Benkow 1957; Dalit 1964; Renggli et al 1971). Devices which are coupled to the source require laboratory fabrication and are somewhat uncomfortable for the patient. Uncoupled devices are more comfortable for the patient and can be fabricated chairside (Duckworth et al 1983).

Deck (1969) compared measurements of certain tooth
dimensions on the radiographs prior to extraction and in the tooth after its extraction using the Stereo-Fix device (Dalitz 1964), the Ortholator (Kaletsky 1939), the Medwedeff device (Medwedeff, Knox & Latimer 1967), and conventional long cone paralleling technique. She reported that most measurements could be obtained almost as accurately from conventional techniques as from the use of positioning devices.

Radiograph standardization techniques require special equipment and are thus more time consuming than routine surveys. Perhaps for these reasons, no approach to standardization has gained widespread acceptance (Hurt 1977).

5.2.3 Radiographic Scoring Systems on Periodontal Bone Level Changes

The different scoring systems for measuring bone levels on radiographs were reviewed by Bjorn (1968). The diversity of reference levels and disparity of scales of various systems are rather confusing.

1. Reference levels. The bone height may be given in divisions of the distance from cemento-enamel junction to apex; or the scale may relate to an optimal bone height which is considered to be situated at a distance varying from one to three millimeters apically from
the cemento-enamel junction. In other systems, the bone height is related to the total length of the tooth.

2. Scales. The scales grading the degree of bone loss may be given in scores from 0 to 10; 0 to 5; 0 to 4; tenths of the maximum bone height or of the total tooth length according to various authors.

Bjorn (1968) recommended that bone destruction be related to the complete length of the tooth because of uncertainties in locating the cemento-enamel junction. The use of a scale with radiating lines is to be avoided because it may lead to false scores.

Ramfjord (1974) recommended a method of Bjorn (1969) which employed a graded scale of 20 divisions along the total length of the tooth and reported this may be accurate and practical enough to be used in clinical trials concerning loss or gain of periodontium. Tests of inter- and intra-examiner variability demonstrated a high degree of reproducibility of the readings (Cain 1971).

Radiographic indices are at best only relative expressions of the amount of bone destruction. It is important to realise that one equidistant division of the scale does not depict an equal amount of bone loss, therefore caution must be exercised when the amount of bone loss between different teeth (e.g. between anterior and posterior) are compared on the scale.
Recently a new technique detecting small temporal changes in supporting bone by the subtraction of two serially-obtained radiographs has been developed (Hardestedt & Welander 1975; Webber, Ruttimann & Grondahl 1982). This is based on the fact that unchanged anatomic structures cancel in the subtraction image, resulting in a less complex background against which tissue changes can be seen more readily.

However, any artifacts produced by inexact replication of the projection geometry, variations in film exposure and processing, and tissue changes from normal growth and development would interfere with the interpretation of the subtraction image. Further research is needed before this method can be applied to clinically realistic situations.
6. INDICES FOR MEASUREMENT OF PERIODONTAL TREATMENT NEEDS.

Up to the late sixties, the development of periodontal indices has been towards more finely graded indices which are well suited for evaluation of short term clinical trials. The increased sensitivity, though advantageous for scientific research, is not always practical from a public dental health point of view.

These indices tend to register a positive score for the vast majority of the population. They provide the public health planner with only the most peripheral information about treatment needs and nothing about treatment achievement or failure.

In assessing the treatment needs of a population, it is doubtful whether the total elimination of plaque and gingivitis are realistic treatment goals. Priority in treatment must be laid down and given to those with the greatest need. The major difficulty is to differentiate those deviations from normal which are transient and reversible and those that are progressive unless some therapeutic measures are instigated (Davies 1977).

Barmes (1976) listed the following objectives for a public health planner in periodontal disease assessment:
1. Evaluation of treatment needs as the main basis for manpower and cost calculations;
2. Evaluation of treatment met to indicate how much of need is being serviced;
3. Evaluation of treatment failed as a quality assessment;
4. Allocation of treatment categories to available resources;
5. Measuring the benefit of a particular treatment programme relative to the cost of delivering that programme.

A number of studies have considered the question of evaluating the periodontal treatment needs of individual populations (Cross 1952; Russell 1956; Davies 1961; O'Leary et al 1967; McPhee 1967; Johansen 1970; W.H.O. 1971; Heloe 1973; Bellini 1973; Johansen, Gjermo & Bellini 1973; Hill 1974; Ainamo & Bay 1975; Møller & Beck 1976).

An index designed to measure treatment need requirements for periodontal diseases should possess the attribute of any good index. In addition it should provide a measurement of the time needed for and the complexity of treatment in planning oral health care.
6.1 W.H.O. (1971) - ORAL HEALTH SURVEYS - BASIC METHODS.


A rapid full mouth examination was conducted only with a mouth mirror. Scores of 0, 1 and 2 were given to normal, gingivitis and periodontitis respectively. The criteria of scoring were similar to the PI of Russell. A decision was made on the presence of periodontal pocket without the use of a periodontal probe.

The only assessment or treatment need was for the number of teeth that must be extracted for periodontal reasons.

Davies et al (Davies, Horowitz & Wada 1974) conducted examinations using the method and found poor comparability with these simple measurements. Barmes (1976) stated that the stark percentages of samples having gingivitis or periodontitis were too crude a treatment need indicator for most administrators.
6.2 THE PERIODONTAL TREATMENT NEEDS SYSTEM  
(PTNs, BELLINI & JOHANSEN)

This system was developed by Bellini and Johansen (Bellini 1973; Johansen et al 1973; 1979) to determine periodontal therapeutic needs of populations by estimating type(s) of treatment needed and the time required for performing it; thus enabling the calculation of manpower requirements and costs.

Subjects are classified into 3 treatment classes according to the presence or absence of plaque, calculus, overhangs, gingival inflammation and periodontal pockets deeper than 5 mm.

Using a mouth mirror and a blunt periodontal probe, all gingival areas on each tooth are probed. Any quadrant with a pocket deeper than 5 mm is scored C. Where there are gingivitis, overhangs and calculus but no pockets, B is scored. When only plaque and gingivitis are present, the score is A. By estimating the number of quadrants in each class, the estimation of treatment time can be made. The following time allotments are suggested:

<table>
<thead>
<tr>
<th>PTNS Class</th>
<th>Treatment Required</th>
<th>Time Allotment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No treatment</td>
<td>0</td>
</tr>
<tr>
<td>A</td>
<td>Motivation &amp; oral hygiene instruction</td>
<td>each patient 60 minutes</td>
</tr>
<tr>
<td>B</td>
<td>Above + Scaling</td>
<td>each quadrant 60 minutes</td>
</tr>
<tr>
<td>C</td>
<td>Above + Surgery</td>
<td>each quadrant 60 minutes</td>
</tr>
</tbody>
</table>
When calculating the treatment time requirements, a quadrant with score C is regarded as automatically rated score B for calculus or overhang and rated score A for plaque and gingivitis.

These are only rough estimates for calculating the needs on a population basis. Time for treatment of individual patient may vary according to level of cooperation, general health and the number of remaining teeth (Bellini 1974).

Because various treatment procedures are estimated separately, the PTNS lends itself to planning the employment of different categories of dental health personnel and analysis of costs (Bellini & Bjermo 1973).

Johansen et al (1973) found the PTNS to be reproducible and sensitive for predicting treatment needed and the time for treatment. However no attempt is made to define priority of treatment between groups. Probing all gingival areas for pockets may be too lengthy a procedure for screening large populations. It is also an unproven assumption that all pockets in excess of 5 mm require surgical elimination (McPhee 1977).
6.3 W.H.O. (1977) - ORAL HEALTH SURVEYS - BASIC METHODS.


The aim of the assessment was to select a method which was simple and yet provided a greater range of disease status measurements as well as a guide to treatment needs.

Some studies relevant in the formulation of the W.H.O. (1977) method were:

1. The Periodontal Screening System of O'Leary (1967);
2. Visible Plaque Index, Gingival and Periodontal Site Prevalence Index of Ainamo (Ainamo & Bay 1975);
3. Periodontal Treatment Need System of Bellini (1973) and Johansen et al (1973) and

6.3.1 The Methodology of Assessment

In the 2nd edition, the mouth is divided into six segments for scoring purposes as proposed by O'Leary (1967). This approach is more sensitive than treating the entire mouth as one unit in the 1st edition.
The presence or absence of soft deposits, calculus, intense gingivitis, and advanced periodontal involvement are recorded for each segment on a dichotomous scale of 1 and 0 as proposed by Ainamo & Bay (1975). The presence of soft deposits is detected only with the use of a mouth mirror; a probe is not used. Calculus is recorded for the segment when it is obviously present. A probe may be used to confirm that a deposit is, in fact, calcified.

Davies et al (1974) originally proposed four severity gradings for scoring periodontal disease in the 2nd edition. However, to simplify recording procedures and ensure comparability of results, only two categories, intense gingivitis and advanced periodontal involvement, are retained.

Intense gingivitis is recorded if there is a marked change in gingival colour or if firm digital palpation causes bleeding. Examiners are instructed to palpate only if there is doubt whether bleeding will occur.

Advanced periodontal involvement is recorded when there is definite tooth mobility or a periodontal pocket greater than 3 mm in depth that is accompanied by intense gingivitis, marked change in gingival contour, suppuration or advanced recession with exposure of cementum.

If there is no mobility, a periodontal probe is used to check for a pocket only if one or the four necessary
conditions is present. Multiple probings are discouraged. All probings should cease as soon as a pocket deeper than 3 mm is found.

The questionable method of estimating the number of teeth extracted because of a periodontal disease was dropped in the revised edition.

In the combined oral health and treatment requirement portion of the revised edition, each subject is further classified into one of six categories of treatment requirements based on the oral examination:

1. No treatment necessary.
2. Oral hygiene instruction.
3. Prophylaxis and oral hygiene instruction.
4. Periodontal therapy without extraction of any teeth for periodontal reasons.
5. Treatment which includes the extraction of one or more, but not all, teeth for periodontal reasons.
6. Full extraction.

6.3.2 Deficiencies of the Method.

The manual openly admits to accepting compromises in criteria for both the assessments of periodontal status and the need for treatment. The compromises were conceded so as to reduce the inter- and intra-examiner variations
to a minimum. They were also necessary so that the subjects would not be unduly stressed during the examination.

McPhee (1977) criticised the term "intense gingivitis" as complicating an already complex glossary in gingivitis terminology. The provision in distinguishing a contained gingivitis from the destructive lesion was poor. Also significant tissue destruction and pocket formation may exist in the absence of tooth mobility or any of the four conditions said to be accompanying pocketing in the manual.

Horowitz (1979) suggested a periodontal assessment solely from vision and digital palpation. The use of periodontal probes by examiners with varying levels of training in field trials would be a primary concern in the comparability of data. He also believed a periodontal pocket of 5 mm rather than 3 mm should be regarded as evidence of advanced periodontal involvement.

The combined oral health and treatment assessment has not provided estimates of time requirements for care. Subjects requiring full extractions for periodontal disease may be treated more easily in less time than those who are listed in a less severe category. Thus the severity of the periodontal condition is not a good indicator for the treatment time required (Horowitz 1979).

Cutress, Hunter, Beck & de Souza (1977) compared the method of periodontal assessment in the 2nd edition to PI
of Russell and OHI of Greene and Vermillion. They found that the PI and OHI were more objective, quantitative and sensitive than the W.H.O. (1977) method. Much difficulty of examiner calibration was experienced in the diagnosing of "intense gingivitis". Examiners considered it particularly misleading to score positive for intense gingivitis for a segment where only one interdental unit was involved, quite commonly associated with a restoration.
6.4  COMMUNITY PERIODONTAL INDEX OF TREATMENT NEEDS
(CPITN, Ainamo et al.)


6.4.1 The Methodology of the CPITN

The CPITN is based on the examination of six segments of the dentition, from second molars to first premolars and from canines to canines. One recording only is made for each of these sextants. Severity gradings are avoided in favour of a single present/absent classification.

In epidemiological surveys, the recordings are based on examination of specified index teeth: the two molars in each posterior sextant and one central incisor in each of the two anterior sextants. An alternative procedure is to base the recording on the worst condition found around any one of the four or six teeth comprising the sextant.

The use of a special W.H.O. designed periodontal probe, the 621 periodontal probe (Emslie 1980) is recommended.
It has a colour coded band 3.5 - 5.5 mm from the ball pointed tip. If this disappears into the pocket during probing, the pocket depth is 6 mm or more and gives a sextant a code of 4. If the coloured area remains partly visible, the pocket depth is 4 mm or 5 mm and code 3 is given. If the entire coloured band remains visible, code 2 is given if supragingival or subgingival calculus is present. Correspondingly code 1 is recorded if the pocket depth is 3 mm or less and there is no calculus but bleeding on gentle probing of the pocket or sulcus occurs. Absence of any sign of disease in a sextant qualifying for recording (two or more functioning teeth) is indicated with code 0.

The probing technique as recommended for measuring pocket depth is a working force of no more than 25 g with the ball pointed tip following the anatomic configuration of the root surface. A practical test for establishing this force is to gently insert the probe point under the finger nail without causing pain or discomfort.

Disease status codes are easily converted into four treatment categories. Complex treatment (III) for sextants with 6 mm or deeper pockets (Code 4); scaling (II) for codes 3 and 2; improvement of personal oral hygiene (I) for code 1; and no treatment for absence of disease. Treatment category III also requires treatments
II and I; and treatment category II also requires treatment I.

Ainamo et al. (1982) reports that when only the index teeth are examined or when the recording is based on the worst finding of all teeth in a sextant, the number of probings per sextant rarely needs to exceed four. The time needed for the CPITN in recording the codes for the sextants should not exceed 1-2 minutes.

6.4.2 Utilization of CPITN Data

For evaluations of periodontal treatment needs in a population and for planning purposes, the CPITN recordings can be utilized in different ways.

1. Average severity scores can be obtained by examination of index teeth or all teeth for the presence of deep or moderately deep pockets, calculus or bleeding in the population. However, this is not an accurate reflection of prevalence especially in a population with a low prevalence of the disease. For example if the average severity score of pocketing is 0.8 deep pockets per subject, the corresponding prevalence could be anywhere between 80 and 1 percent depending on whether 80 patients had one deep pocket each or 1 percent had eighty deep pockets.
2. Treatment needs are better reported as the number or percentage of subjects in various age groups in each treatment need category. W.H.O. (1978) recommended periodontal assessments should be reported for four different age groups: 15-19, 20-29, 39-44 and 45-64 years. The 15-19 and 30-45 years groups are most useful for planning.

3. It is often useful to present the mean number of sextants with bleeding, calculus, moderate pockets or deep pockets for each age group.

4. Alternatively, reporting the number and percentage of individuals with (a) no sextant scoring 0, 1 etc, (b) 1-2 sextants scoring 0, 1 etc, (c) 3-4 sextants scoring 0, 1 etc, (d) 5-6 sextants scoring 0, 1 etc. would facilitate identification of high and low risk groups and priorities for treatment.

5. Another approach is to report the results as the average time needed to carry out the procedures in the various treatment categories. Further research is under way before the release of more detailed recommendations.

6.4.3 Evaluations of the CPITN.

The sole use of the 621 probe can diagnose the four categories of disease defined in the CPITN: gingival bleeding
after gentle probing, supra and subgingival calculus, 4-5 mm and 6 mm and over deep pockets. Examiners would not be confronted with the difficulty of deciding over subtle changes of gingival form and colour as in some other indices.

The recommended 25 g. is a very light probing force which will be resisted by healthy epithelial attachment but sufficient to detect re-infected long epithelial attachments and to elicit bleeding from the area of inflammation.

Tooth mobility and gingival recession are not recorded. They represent past periodontal disease experience and are not relevant in the assessment of treatment needs.

The strength of the CPITN lies in its ability to dissect the polarization of disease within different strata of the population. The dental health administrator can be better served by information about the proportions of individuals within various age groups having different levels of periodontal problems.

A complicating factor in the evaluation of community programmes for prevention of periodontal disease is the rarity of a totally healthy periodontium. An often raised question is what level of periodontal health or disease
is acceptable at a given age with a known dentist to population ratio. In an attempt to answer such a question, Ainamo (1983) recently proposed tentative goals for periodontal "health" in Europe in the year 2000.

As a realistic goal, it was suggested that 90 percent of the 18 year olds and 75 percent of the 35-44 age group should have at least three out of six sextants free of gingivitis and periodontal disease as judged by the CPITN. For age 65 and over, less than 10 percent should have deep pockets of 4 mm or more.
In recent years the concept of periodontal disease as a slow progressive condition has been questioned. Longitudinal monitoring of individual sites in subjects has indicated that destruction occurs in relatively short periods of time which are followed by prolonged periods of quiescence (Goodson et al 1982; Haffajee, Socransky & Goodson 1983b).

Haffajee et al (1983a) recently evaluated the usefulness of some clinical parameters in the detection and the prediction of periodontal disease activity. These parameters are generally accepted as being related to periodontal disease and include plaque accumulation, redness, swelling, bleeding on probing, suppuration, crevicular fluid volume, pocket depth and attachment level measured from the cemento-enamel junction to the deepest probeable point in the area.

He reported that while certain parameters had either high sensitivity or specificity, none had both. Further, each clinical parameter had a very high false positive rate. This was expected since prevalence of active destructive sites were estimated at only 3 percent in the mouth (Haffajee et al 1983a). Thus these parameters were found to be unreliable predictors of destructive
disease. Their usefulness as indicators of destruction in the preceding time was also evaluated. Haffajee reported that with the exception of increased attachment loss and deepening of pockets, there was little evidence any of the parameters were useful indicators of past destruction. He concluded that the evaluated parameters were only static measurements of a dynamic process and bear little relationship to the status of destructive periodontal disease activity in the individual site.

In the light of the above studies, Hazen's list of requirements for an ideal periodontal disease index (1974) should be expanded to include the following criteria:

1. distinguish between the active and inactive stages of the disease;
2. be sensitive enough to measure slight changes over short periods of time;
3. compensate for area variability within the oral cavity;
4. differentiate between changes associated with aging and changes associated with disease;
5. be safe.

Most of the indices discussed especially those used in the measurement of plaque and gingival inflammation are non-precise and subjective. It is evident that none of the present index systems fulfill all the desirable criteria of the ideal index.
Investigators at present are directing their efforts in two different but related areas in periodontal indices research. The first is the development of easily applied objective measurements using the existing range of clinical parameters. The investigators are aided here by the recent substantial progress in biomedical technologies and laboratory techniques. Examples of such developments are the use of transmission spectroscopic methods with optic fibre probes to measure gingival colour changes within the periodontal pocket; measurement of gingival bleeding induced by the controlled application of pressure and the application of three dimensional radiography and tomographic analysis on interproximal bone loss (Page 1979; Loe 1979; Goldhaber 1979).

On the other hand, investigators have worked towards the identification of new clinical periodontal disease parameters which can provide physical measurements as well as reflect the cyclic destructive nature of periodontal disease. One of the most important of these new parameters is the pathogenic potential of dental plaque. This is usually related to the identification and quantification of specific micro-organisms, bacterial metabolic end products, antigens and host antibodies (Mandel & Socransky 1979). Other new parameters under investigation include gingival blood flow, gingival temperature, levels of hydrolytic enzymes particularly collagenase, levels of tissue products such as hydroxyproline and levels of bacterial endotoxin in the exudate (Golub 1979).
After the characteristics to be measured are identified, the sensitivity levels have to be determined if the measurements are to have any clinical value. This involves assessing the amount of physical change that can be expected to occur in the disease and the degree of sensitivity of the measurement. It is also necessary to assign priorities so that the relative importance of various measurements can be established.

Many researchers have not yet agreed upon the relevance of these new parameters in periodontal disease, and most of the current methods are too laborious for routine clinical use. Despite their limitations, the feasibility of these techniques in clinical measurement of periodontal disease should be further explored in the search for accurate, sensitive and reproducible methods of recording periodontal disease.
8. CONCLUSIONS

From a literature review of selected periodontal disease indices, the following conclusions are drawn:

Indices of Soft Deposits.

1. For epidemiological studies, the OHI-S is the method of choice. It is also used in clinical non-brushing mouth rinse studies where the gross areas designated by the OHI-S are quite adequate.

2. For gingivitis and tooth brushing studies, indices which emphasise the gingival one-third deposits are recommended, such as the PI I, the Navy Plaque Index, PDI modified by Shick and Ash and Quigley and Hein modified by Turesky.

3. Plaque area measurements in percentages in conjunction with photographic methods are not very reliable.

4. Plaque weight measurement is a more objective yet "destructive" procedure. It is also time consuming.

5. Laboratory analysis of the pathogenic potential of plaque may point to the future of plaque measurements.

Indices of Hard Deposits

1. In epidemiological studies, both the OHI-S and PDI calculus components have been extensively used.
2. In pilot short term (1 to 6 weeks) clinical studies, the Calculus Surface Index (presence or absence of supra and subgingival calculus) and the Marginal Line Calculus Index (extent of supragingival calculus in relation to gingival tissues) are recommended.

3. The actual long term studies involve a large number of subjects and a period of one year or longer. The predominant deposits will be supragingival. The Probe Method of Calculus Assessment is recommended because of its accuracy and reproducibility.

Indices of Gingival Inflammation

1. For epidemiologic surveys, PI and PDI fulfill the requirements. The PDI is more sensitive to the early stages of gingivitis.

2. For clinical studies of gingivitis where accurate assessments are essential, the GI is recommended.

3. The GI was found to compare favourably with two other methods of gingival diagnosis: biopsy and gingival crevicular fluid flow.

4. Gingival bleeding on probing as an objective diagnostic criterion of gingival inflammation is hindered by non-standardized probing forces of various examiners.

5. Photographs are useful in standardizing examiners but the direct measurement of gingivitis from photographs lack reliability.
Indices of Loss or Gain of Soft Tissue Attachment

1. The most common method for determining the level of soft tissue attachment is through the use of a thin periodontal probe (0.35 mm terminal diameter) graduated in millimeter markings.

2. Both PI and PDI are capable of recording advanced periodontal breakdown but are limited to only epidemiological purposes.

3. The level of epithelial attachment in clinical studies is expressed as the distance in millimeters from the cemento-enamel junction to the apical extent of the gingival sulcus or pocket.

4. Periodontal probing accuracy is affected by the probing pressure, the degree of tissue inflammation, and the quality and precision of the periodontal probe itself.

5. Calibration on every probe should be checked for inaccuracies before clinical use and inaccurate probes discarded.

Indices of Bone Loss

1. Radiographs are invaluable in assessing the height of interproximal bone crests.
2. They are recommended particularly in long term clinical periodontitis studies in the comparison of interproximal bone levels.

Indices of Periodontal Treatment Needs

The Community Periodontal Index of Treatment Needs (CPITN) which requires the use of a special probe is recommended for recording the treatment needs of individuals and populations.
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